A design space for social object labels in museums

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Abstract

Taking a problematic user experience with ubiquitous annotation as its point of departure, this thesis defines and explores the design space for Social Object Labels (SOLs), small interactive displays aiming to support users’ in-situ engagement with digital annotations of physical objects and places by providing up-to-date information before, during and after interaction.

While the concept of ubiquitous annotation has potential applications in a wide range of domains, the research focuses in particular on SOLs in a museum context, where they can support the institution’s educational goals by engaging visitors in the interpretation of exhibits and providing a platform for public discourse to complement official interpretations provided on traditional object labels.

The thesis defines and structures the design space for SOLs, investigates how they can support social interpretation in museums and develops empirically validated design recommendations. Reflecting the developmental character of the research, it employs Design Research as a methodological framework, which involves the iterative development and evaluation of design artefacts together with users and other stakeholders.

The research identifies the particular characteristics of SOLs and structures their design space into ten high-level aspects, synthesised from taxonomies and heuristics for similar display concepts and complemented with aspects emerging from the iterative design and evaluation of prototypes. It presents findings from a survey exploring visitors’ mental models, preferences and expectations of commenting in museums and translates them into requirements for SOLs. It reports on scenario-based design activities, expert interviews with museum professionals, formative user studies and co-design sessions, and two empirical evaluations of SOL prototypes in a gallery environment. Pulling together findings from these research activities it then formulates design recommendations for SOLs and supports them with related evidence and implementation examples.

The main contributions are (i) to delineate and structure the design space for SOLs, which helps to ground SOLs in the literature and understand them as a distinct display concept with its own characteristics; (ii) to explore, for the first time, a visitor perspective on commenting in museums, which can inform research, development and policies on user-generated content in museums and the wider cultural heritage sector; (iii) to develop empirically validated design recommendations, which can inform future research and development into SOLs and related display concept.

The thesis concludes by summarising findings in relation to its stated research questions, restating its contributions from ubiquitous computing, domain and methodology perspectives, and discussing open issues and future work.
Brief table of contents

Abstract .......................................................................................................................... ii
Brief table of contents .................................................................................................... iii
Extended table of contents ............................................................................................ vi
List of tables .................................................................................................................. xiii
List of figures .................................................................................................................. xiv
Acknowledgements ....................................................................................................... xvii
Funding and awards ......................................................................................................... xvii
Declaration ..................................................................................................................... xviii

1 Introduction ................................................................................................................. 1
  1.1 Context and motivation ......................................................................................... 1
  1.2 Research focus ....................................................................................................... 4
  1.3 Aims and objectives .............................................................................................. 5
  1.4 Research questions ............................................................................................... 6
  1.5 Contribution .......................................................................................................... 6
  1.6 Thesis overview .................................................................................................... 7
  1.7 Timeline of research activities ............................................................................. 8
  1.8 Terminology .......................................................................................................... 9

2 Literature Review ....................................................................................................... 13
  2.1 Introduction ........................................................................................................... 13
  2.2 Ubicomp perspective ............................................................................................. 15
  2.3 Application perspective ......................................................................................... 35
  2.4 Domain perspective ............................................................................................... 45
  2.5 Methodology perspective ..................................................................................... 59
  2.6 Conclusions .......................................................................................................... 64

3 Methodology ............................................................................................................... 65
  3.1 Introduction ........................................................................................................... 65
  3.2 Overview of research process ............................................................................... 66
  3.3 Approaches and methods ...................................................................................... 68
  3.4 Participants ............................................................................................................ 70
  3.5 Ethical considerations ............................................................................................ 71

4 Design space analysis ............................................................................................... 72
  4.1 Introduction ........................................................................................................... 72
  4.2 Distinguishing SOLs from similar display concepts ............................................. 72
  4.3 Relevant design aspects from related display concepts ....................................... 74
  4.4 Synthesis of design aspects from related display concepts .................................. 83
  4.5 Additional aspects emerging from design and evaluation activities .................. 84
  4.6 Review and consolidation ..................................................................................... 87
  4.7 Ten design aspects ............................................................................................... 88
  4.8 Discussion ............................................................................................................. 90
5 Visitor perspective on commenting in museums .................................................. 94
  5.1 Introduction ........................................................................................................ 94
  5.2 Method and instrument ..................................................................................... 96
  5.3 Findings .............................................................................................................. 99
  5.4 Discussion ......................................................................................................... 120
  5.5 Limitations ....................................................................................................... 122
  5.6 Conclusions ...................................................................................................... 123
  6 User and scenario modelling .............................................................................. 124
  6.1 Introduction ........................................................................................................ 124
  6.2 Target users ...................................................................................................... 124
  6.3 Audience research .......................................................................................... 124
  6.4 Personas ........................................................................................................... 130
  6.5 Scenarios .......................................................................................................... 137
  6.6 Limitations ....................................................................................................... 147
  6.7 Conclusions ...................................................................................................... 147
  7 Expert interviews ................................................................................................ 148
  7.1 Introduction ....................................................................................................... 148
  7.2 Methodology .................................................................................................... 148
  7.3 Findings ............................................................................................................ 149
  7.4 Limitations ....................................................................................................... 156
  7.5 Conclusions ...................................................................................................... 157
  8 Prototype design and evaluation ........................................................................ 158
  8.1 Starting point and trajectory ............................................................................ 158
  8.2 Early prototyping .............................................................................................. 159
  8.3 Field trial 1: Fail Better .................................................................................... 170
  8.4 Formative user-testing and co-design ............................................................... 187
  8.5 Field trial 2: Home\Sick .................................................................................. 209
  9 Design recommendations .................................................................................... 258
  9.1 Openness .......................................................................................................... 259
  9.2 Plasticity ........................................................................................................... 262
  9.3 Interrogability .................................................................................................. 265
  9.4 Ease of engagement ......................................................................................... 266
  9.5 Interaction modality ......................................................................................... 269
  9.6 User control ...................................................................................................... 272
  9.7 Content moderation ......................................................................................... 274
  9.8 Information design ........................................................................................... 276
  9.9 Conspicuousness ............................................................................................. 279
  9.10 Robustness ..................................................................................................... 280
10 Conclusions .................................................................................................................. 283
10.1 Summary of findings ............................................................................................... 284
10.2 Learning about the process ................................................................................... 286
10.3 Restatement of contributions ................................................................................. 286
10.4 Open issues and future work .................................................................................. 288
10.5 Closing remarks ...................................................................................................... 290
Related publications ....................................................................................................... 291
References ...................................................................................................................... 292
Appendix A: Complete list of formative findings ....................................................... 315
Appendix B: Technical overview of SOL prototypes ................................................. 324
Appendix C: System architectures and their implications ............................................ 340
Appendix D: Instrument for museum visitor survey on commenting ....................... 346
Appendix E: Instrument for interviews with museum professionals ......................... 363
Appendix F: Instrument for formative user testing and co-design sessions ............... 367
Appendix G: Instrument for empirical evaluation 1: Fail Better ................................. 392
Appendix H: Instrument for empirical evaluation 2: Home\Sick ................................. 405
## Extended table of contents

Abstract .................................................................................................................. ii

Brief table of contents ............................................................................................. iii

Extended table of contents ...................................................................................... vi

List of tables ............................................................................................................. xiii

List of figures ........................................................................................................... xiv

Acknowledgements ................................................................................................. xvii

Funding and awards................................................................................................. xviii

Declaration ................................................................................................................. xviii

1 Introduction ........................................................................................................... 1

1.1 Context and motivation ....................................................................................... 1

1.2 Research focus .................................................................................................... 4

1.3 Aims and objectives ............................................................................................ 5

1.4 Research questions ............................................................................................. 6

1.5 Contribution ......................................................................................................... 6

1.6 Thesis overview .................................................................................................. 7

1.7 Timeline of research activities ............................................................................. 8

1.8 Terminology ......................................................................................................... 9

2 Literature Review .................................................................................................. 13

2.1 Introduction ......................................................................................................... 13

2.1.1 Aims of the review .......................................................................................... 13

2.1.2 Perspectives on the problem space ................................................................. 14

2.2 Ubicomp perspective .......................................................................................... 15

2.2.1 Display taxonomies and design guidelines ..................................................... 15

2.2.1.1 Ambient displays ....................................................................................... 15

2.2.1.2 Interactive public displays ......................................................................... 16

2.2.1.3 Summary ..................................................................................................... 17

2.2.2 Awareness and engagement ............................................................................ 17

2.2.2.1 Peripheral attention and engagement ........................................................ 17

2.2.2.2 Focused attention and engagement ........................................................... 18

2.2.2.3 Summary ..................................................................................................... 21

2.2.3 Physical mobile interaction ............................................................................. 23

2.2.3.1 Introduction ................................................................................................. 23

2.2.3.2 Object identification .................................................................................. 24

2.2.3.3 Interaction models ...................................................................................... 26

2.2.3.4 User experience ......................................................................................... 28

2.2.3.5 Summary ..................................................................................................... 31

2.2.4 Deployment ...................................................................................................... 31

2.2.5 Summary of ubicomp perspective .................................................................... 33

2.3 Application perspective ..................................................................................... 35
8 Prototype design and evaluation .................................................. 158
8.1 Starting point and trajectory ..................................................... 158
8.2 Early prototyping ................................................................. 159
8.2.1 Prototype 1 ................................................................. 159
8.2.2 Prototype 2 ................................................................. 160
8.2.3 Prototype 3 ................................................................. 163
8.2.4 Prototype 4 ................................................................. 165
8.2.5 Limitations ................................................................. 168
8.2.6 Conclusions ............................................................... 168
8.3 Field trial 1: Fail Better .......................................................... 170
8.3.1 Introduction ................................................................. 170
8.3.2 Gallery deployment ........................................................ 170
8.3.2.1 Placement ............................................................. 172
8.3.2.2 Framing ................................................................. 172
8.3.2.3 Technical integration .................................................. 173
8.3.2.4 Information environment ............................................ 173
8.3.2.5 Interaction environment ............................................. 173
8.3.3 Methodology ................................................................. 175
8.3.3.1 Visitor observations .................................................. 176
8.3.3.2 Visitor interviews ...................................................... 176
8.3.3.3 Staff interviews ....................................................... 176
8.3.4 Findings ................................................................. 177
8.3.4.1 Attention and interaction ............................................. 177
8.3.4.2 Visitor perspective on SOLs ....................................... 178
8.3.4.3 Museum perspective on SOLs ..................................... 180
8.3.5 Discussion ................................................................. 181
8.3.5.1 Design implications for SOLs ..................................... 181
8.3.5.2 Design implications for the mobile application ............... 183
8.3.5.3 Design implications for the admin interface .................... 183
8.3.6 Reflection on collaboration and research environment .......... 183
8.3.7 Limitations ................................................................. 184
8.3.8 Conclusions ............................................................... 185
8.4 Formative user-testing and co-design ........................................ 187
8.4.1 Introduction ............................................................... 187
<table>
<thead>
<tr>
<th>Chapter</th>
<th>Title</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>9</td>
<td>Design recommendations</td>
<td>258</td>
</tr>
<tr>
<td>9.1</td>
<td>Openness</td>
<td>259</td>
</tr>
<tr>
<td>9.1.1</td>
<td>Content creation</td>
<td>259</td>
</tr>
<tr>
<td>9.1.2</td>
<td>Content syndication</td>
<td>259</td>
</tr>
<tr>
<td>9.1.3</td>
<td>Social media integration</td>
<td>260</td>
</tr>
<tr>
<td>9.1.4</td>
<td>Content conservation</td>
<td>261</td>
</tr>
<tr>
<td>9.1.5</td>
<td>Transparency</td>
<td>262</td>
</tr>
<tr>
<td>9.2</td>
<td>Plasticity</td>
<td>262</td>
</tr>
<tr>
<td>9.2.1</td>
<td>Customisation</td>
<td>262</td>
</tr>
<tr>
<td>9.2.2</td>
<td>Configuration</td>
<td>263</td>
</tr>
<tr>
<td>9.2.3</td>
<td>Deployment</td>
<td>264</td>
</tr>
<tr>
<td>9.2.4</td>
<td>Scalability</td>
<td>264</td>
</tr>
<tr>
<td>9.3</td>
<td>Interrogability</td>
<td>265</td>
</tr>
<tr>
<td>9.3.1</td>
<td>System status</td>
<td>265</td>
</tr>
<tr>
<td>9.3.2</td>
<td>Analytics data</td>
<td>266</td>
</tr>
<tr>
<td>9.4</td>
<td>Ease of engagement</td>
<td>266</td>
</tr>
<tr>
<td>9.4.1</td>
<td>Streamline engagement</td>
<td>266</td>
</tr>
<tr>
<td>9.4.2</td>
<td>Peripheral participation</td>
<td>267</td>
</tr>
<tr>
<td>9.4.3</td>
<td>Supporting information</td>
<td>267</td>
</tr>
<tr>
<td>9.4.4</td>
<td>Supporting environment</td>
<td>268</td>
</tr>
<tr>
<td>9.4.5</td>
<td>Ergonomy</td>
<td>269</td>
</tr>
<tr>
<td>9.5</td>
<td>Interaction modality</td>
<td>269</td>
</tr>
<tr>
<td>9.5.1</td>
<td>Interaction modes and technologies</td>
<td>269</td>
</tr>
<tr>
<td>9.5.2</td>
<td>Distribution of functionality</td>
<td>270</td>
</tr>
<tr>
<td>9.5.3</td>
<td>Multi-user support</td>
<td>271</td>
</tr>
<tr>
<td>9.5.4</td>
<td>Social acceptance</td>
<td>271</td>
</tr>
<tr>
<td>9.6</td>
<td>User control</td>
<td>272</td>
</tr>
<tr>
<td>9.6.1</td>
<td>Personal information</td>
<td>272</td>
</tr>
<tr>
<td>9.6.2</td>
<td>Format and topic</td>
<td>272</td>
</tr>
<tr>
<td>9.6.3</td>
<td>Submitted content</td>
<td>273</td>
</tr>
<tr>
<td>9.6.4</td>
<td>Agency in community</td>
<td>273</td>
</tr>
<tr>
<td>9.6.5</td>
<td>Interaction feedback</td>
<td>274</td>
</tr>
<tr>
<td>9.7</td>
<td>Content moderation</td>
<td>274</td>
</tr>
<tr>
<td>9.7.1</td>
<td>Separation of monitoring and moderation</td>
<td>274</td>
</tr>
<tr>
<td>9.7.2</td>
<td>Monitoring</td>
<td>275</td>
</tr>
<tr>
<td>9.7.3</td>
<td>Moderation</td>
<td>275</td>
</tr>
<tr>
<td>9.8</td>
<td>Information design</td>
<td>276</td>
</tr>
<tr>
<td>9.8.1</td>
<td>Glanceability</td>
<td>276</td>
</tr>
<tr>
<td>9.8.2</td>
<td>Learnability</td>
<td>276</td>
</tr>
<tr>
<td>9.8.3</td>
<td>Persuasiveness</td>
<td>277</td>
</tr>
</tbody>
</table>
9.8.4  Text information ................................................................. 278
9.8.5  Graphical symbols ............................................................. 278
9.9  Conspicuousness ................................................................. 279
9.9.1  Physical design .................................................................. 279
9.9.2  Placement ......................................................................... 279
9.10  Robustness ........................................................................ 280
9.10.1  Physical robustness .......................................................... 280
9.10.2  Technical robustness ......................................................... 281
9.10.3  Interaction robustness ...................................................... 281
9.10.4  Maintenance support ......................................................... 282
10  Conclusions ........................................................................ 283
10.1  Summary of findings .......................................................... 284
10.2  Learning about the process ................................................... 286
10.3  Restatement of contributions ............................................... 286
10.4  Open issues and future work ............................................... 288
10.5  Closing remarks .................................................................. 290
Related publications .................................................................. 291
References ................................................................................ 292
Appendix A: Complete list of formative findings ............................. 315
Appendix B: Technical overview of SOL prototypes ......................... 324
Appendix C: System architectures and their implications ................. 340
Appendix D: Instrument for museum visitor survey on commenting .... 346
Appendix E: Instrument for interviews with museum professionals .......... 363
Appendix F: Instrument for formative user testing and co-design sessions 367
Appendix G: Instrument for empirical evaluation 1: Fail Better ........... 392
Appendix H: Instrument for empirical evaluation 2: Home\Sick ............ 405
List of tables

Table 1: Hansen's (2006) taxonomy for presenting ubiquitous annotations ......................... 12
Table 2: Four interaction metaphors for PMI and related user expectations ....................... 28
Table 3: Differences between social object annotation and place-based messaging .............. 37
Table 4: Bradburne's (2002) five common user languages in museums ............................ 46
Table 5: Subset of guidelines for interpretive labels and related findings ............................ 49
Table 6: Taxonomy for ubicomp evaluation methods ....................................................... 61
Table 7: Mapping outcomes of Design Research to outcomes of the present research ...... 68
Table 8: Overview of approaches and methods used in the research ................................. 69
Table 9: Ames and Dey’s (2002) design dimensions for ambient displays ........................ 75
Table 10: Mankoff and Dey’s (2003) heuristics for ambient displays ............................... 76
Table 11: Brewer’s (2004) taxonomy dimensions for ambient displays ............................. 77
Table 12: Pousman and Stasko’s (2006) taxonomy for ambient information systems ......... 78
Table 13: Tomitsch et al.’s (2008) taxonomy ambient information systems ..................... 79
Table 14: Ballagas et al.’s (2004) considerations for interaction with public displays ........... 80
Table 15: Mueller et al.’s (2010) taxonomy for interactive public displays ...................... 81
Table 16: Dix and Sas’ (2011) design aspects for interactive public displays ..................... 82
Table 17: Participating institutions ...................................................................................... 98
Table 18: NRS social grades. Source MRS (2006) .............................................................. 125
Table 19: NS-SEC social classes. Source ONS (2011) ......................................................... 126
Table 20: New social classes in the Great British Class Survey .......................................... 126
Table 21: 2005 and 2010 versions of the ACORN classification ....................................... 127
Table 22: Insight Value Group Scale ................................................................................. 127
Table 23: Visitor identities synthesised from Falk (2009, 2010) ......................................... 128
Table 24: Culture segments ................................................................................................. 129
Table 25: Interviewee identifiers and roles in their organisations ....................................... 148
Table 26: Qualitative observations of participants’ interactions with the SOL .................. 193
Table 27: Participants' interactions and utterances while completing the user task ............ 196
Table 28: Attention potential of individual SOL installations ........................................... 214
Table 29: Interactive exhibits in Home\Sick ....................................................................... 218
Table 30: Data sets and their purpose ................................................................................. 222
Table 31: Analytics data fields and their purpose ................................................................. 225
Table 32: Estimates of potential encounters with SOLs and designs .................................. 228
Table 33: Differences in attention rates between evaluated design variables .................... 232
Table 34: Differences in direct engagement rates between design variations ..................... 235
Table 35: Differences in mobile engagement rates between design variations .................... 236
Table 36: Differences in contribution rates between design variations .............................. 237
Table 37: Interface elements assumed to be interactive touch targets ................................. 240
Table 38: Example answers for motivations and barriers to engagement ........................... 247
Table 39: Attention potential and measured attention and engagement ............................ 252
Table 40: Key to findings from research activities ............................................................... 258
Table 41: Mapping research objectives to research aims and thesis chapters ................. 283
**List of figures**

<table>
<thead>
<tr>
<th>Figure</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Figure 1</td>
<td>Generic Social Object Label (SOL)</td>
<td>3</td>
</tr>
<tr>
<td>Figure 2</td>
<td>Timeline of research activities</td>
<td>8</td>
</tr>
<tr>
<td>Figure 3</td>
<td>Google Trends for ubiquitous computing terminology</td>
<td>11</td>
</tr>
<tr>
<td>Figure 4</td>
<td>Social widgets commonly found on the World Wide Web</td>
<td>35</td>
</tr>
<tr>
<td>Figure 5</td>
<td>Overview of research process</td>
<td>66</td>
</tr>
<tr>
<td>Figure 6</td>
<td>Common commenting mechanisms in museums</td>
<td>94</td>
</tr>
<tr>
<td>Figure 7</td>
<td>Visitor survey participants' age range and gender distribution</td>
<td>100</td>
</tr>
<tr>
<td>Figure 8</td>
<td>Visitor survey participants' other demographics</td>
<td>100</td>
</tr>
<tr>
<td>Figure 9</td>
<td>Visitor survey participants' visiting habits</td>
<td>101</td>
</tr>
<tr>
<td>Figure 10</td>
<td>Visitor survey participants' inclination to read object labels</td>
<td>102</td>
</tr>
<tr>
<td>Figure 11</td>
<td>Visitor survey participants' inclination to read and write visitor comments</td>
<td>102</td>
</tr>
<tr>
<td>Figure 12</td>
<td>Visitor survey participants' communication in the gallery space</td>
<td>103</td>
</tr>
<tr>
<td>Figure 13</td>
<td>Visitor survey participants' online communication</td>
<td>104</td>
</tr>
<tr>
<td>Figure 14</td>
<td>Visitor survey participants' views on common commenting mechanisms</td>
<td>105</td>
</tr>
<tr>
<td>Figure 15</td>
<td>Visitor survey participants' views on providing additional information</td>
<td>110</td>
</tr>
<tr>
<td>Figure 16</td>
<td>Visitor survey participants' views on who should read submitted comments</td>
<td>111</td>
</tr>
<tr>
<td>Figure 17</td>
<td>Visitor survey participants' views on moderation</td>
<td>113</td>
</tr>
<tr>
<td>Figure 18</td>
<td>Visitor survey participants' views on decision making in moderation</td>
<td>114</td>
</tr>
<tr>
<td>Figure 19</td>
<td>Visitor survey participants' views on conservation of comments</td>
<td>115</td>
</tr>
<tr>
<td>Figure 20</td>
<td>Visitor survey participants' views on digitisation of comments</td>
<td>116</td>
</tr>
<tr>
<td>Figure 21</td>
<td>Visitor survey participants' views on comment use</td>
<td>117</td>
</tr>
<tr>
<td>Figure 22</td>
<td>Visitor survey participants' views on displaying terms of use</td>
<td>118</td>
</tr>
<tr>
<td>Figure 23</td>
<td>Visitor survey participants' views on ownership of comments</td>
<td>119</td>
</tr>
<tr>
<td>Figure 24</td>
<td>SOL prototype 1</td>
<td>159</td>
</tr>
<tr>
<td>Figure 25</td>
<td>SOL prototype 2</td>
<td>161</td>
</tr>
<tr>
<td>Figure 26</td>
<td>SOL prototype 3</td>
<td>163</td>
</tr>
<tr>
<td>Figure 27</td>
<td>SOL prototype 4</td>
<td>166</td>
</tr>
<tr>
<td>Figure 28</td>
<td>SOL prototype 5</td>
<td>170</td>
</tr>
<tr>
<td>Figure 29</td>
<td>SOL installed next to Superman's Wheelchair</td>
<td>171</td>
</tr>
<tr>
<td>Figure 30</td>
<td>SOL installed next to Apparatus for Facilitating the Birth of a Child</td>
<td>171</td>
</tr>
<tr>
<td>Figure 31</td>
<td>SOLs installed next to and below object label</td>
<td>172</td>
</tr>
<tr>
<td>Figure 32</td>
<td>Twitter printer installed in the ground floor gallery</td>
<td>174</td>
</tr>
<tr>
<td>Figure 33</td>
<td>Fail Wall in the first floor gallery</td>
<td>174</td>
</tr>
<tr>
<td>Figure 34</td>
<td>Touch screen with additional video footage for Superman's Wheelchair</td>
<td>175</td>
</tr>
<tr>
<td>Figure 35</td>
<td>Observed visitor attention and interaction with SOLs</td>
<td>177</td>
</tr>
<tr>
<td>Figure 36</td>
<td>Interviewees' age and smartphone ownership</td>
<td>178</td>
</tr>
<tr>
<td>Figure 37</td>
<td>Interviewees' self-reported awareness of SOLs</td>
<td>179</td>
</tr>
<tr>
<td>Figure 38</td>
<td>Interviewees' assumptions about interactivity</td>
<td>179</td>
</tr>
<tr>
<td>Figure 39</td>
<td>Interviewees' expectations of content and barriers to engagement</td>
<td>180</td>
</tr>
<tr>
<td>Figure 40</td>
<td>Pop-up usability stall for formative user-testing and evaluation</td>
<td>188</td>
</tr>
</tbody>
</table>
Figure 41: Mocked-up a gallery scenario for formative user-testing .................................................. 189
Figure 42: Formative user-testing participants' demographics ................................................................. 190
Figure 43: Formative user-testing participants' digital literacy ................................................................. 191
Figure 44: Formative user-testing interaction times .................................................................................. 195
Figure 45: Design options for SOL casings and participants' preferences .................................................. 198
Figure 46: Design options for the idle screens and participants' preferences ............................................ 200
Figure 47: Design options for the Add buttons and participants' preferences ............................................ 201
Figure 48: Domain name variations and participants' preferences ............................................................ 202
Figure 49: Help screen and participants' preferences ................................................................................. 204
Figure 50: Idle screen designs and participants’ preferences ..................................................................... 206
Figure 51: SOL1 integrated with Parasite Farm .......................................................................................... 211
Figure 52: SOL2 integrated with LillyBot 2.0 ......................................................................................... 211
Figure 53: SOL3 integrated with Ritual Machines .................................................................................... 212
Figure 54: SOL4 next to Dust Matter(s) ..................................................................................................... 212
Figure 55: SOL casing used in Home\Sick exhibition .................................................................................. 213
Figure 56: Questions posed on SOLs in Home\Sick ................................................................................. 215
Figure 57: SOL Help screen for Dust Matters ............................................................................................ 215
Figure 58: Flyer explaining the purpose and use of SOLs to visitors ......................................................... 216
Figure 59: Admin panel and email alerts for administrators ..................................................................... 217
Figure 60: Exhibit-specific icons displayed on SOLs in Home\Sick ........................................................... 217
Figure 61: Selection of interactive exhibits in Home\Sick ......................................................................... 219
Figure 62: Interaction models for SOL designs with and without content browsing ................................. 220
Figure 63: Overview of evaluated SOL designs ......................................................................................... 221
Figure 64: Interviewees' gender and age ................................................................................................... 224
Figure 65: Interviewees' digital literacy .................................................................................................... 224
Figure 66: Direct interaction session with four user journeys ..................................................................... 226
Figure 67: Direct interaction session with three user journeys .................................................................. 226
Figure 68: Direct interaction session with two user journeys ................................................................... 226
Figure 69: Histogram of time intervals between interactions on SOL touch screen .................................. 227
Figure 70: Screenshot of analytics data visualisation tool .......................................................................... 229
Figure 71: Observed attention to SOLs per exhibit ................................................................................... 231
Figure 72: Attention to SOL and object label ............................................................................................. 231
Figure 73: Attention to SOL per design variation ....................................................................................... 232
Figure 74: Direct engagement with SOLs per exhibit ............................................................................... 233
Figure 75: Mobile engagement with SOLs per exhibit .............................................................................. 234
Figure 76: Contribution rates per exhibit ................................................................................................. 234
Figure 77: Direct engagement rates per design variation .......................................................................... 235
Figure 78: Mobile engagement rates per design variation ....................................................................... 236
Figure 79: Contribution rates per design variation ................................................................................... 237
Figure 80: Accumulated touches for designs with and without content browsing ..................................... 238
Figure 81: Accumulated touches for browse screen .................................................................................. 239
Figure 82: Visitors’ mobile interaction with SOLs ..................................................................................... 241
Figure 83: Use of different mobile connection methods ................................................. 241
Figure 84: NFC symbols: manufacturer’s design and custom design ............................ 242
Figure 85: Time between touch screen interaction and mobile interaction .................... 242
Figure 86: Functionality used after connecting mobile device to SOL ............................ 243
Figure 87: Interviewees’ assumptions about the purpose of SOLs ................................ 244
Figure 88: Interviewees’ assumptions about interactivity and mode of interaction. .......... 244
Figure 89: Assumed content of SOLs ........................................................................... 245
Figure 90: Factors influencing engagement and content contribution ........................... 246
Figure 91: Visitors’ attitudes to mobile phone use in galleries ....................................... 248
Figure 92: SOL usability, satisfaction and intent to use again ....................................... 249
Figure 93: Attention potential and measured attention and engagement ........................ 252
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Declaration

I declare that the research contained in this thesis, unless otherwise formally indicated within the text, is the original work of the author. The thesis has not been previously submitted to this or any other university for a degree, and does not incorporate any material already submitted for a degree.

Signed Marcus Winter

Dated 8 August 2016
Chapter 1

Introduction

1.1 Context and motivation

The proliferation of networked computing resources, carried by people and embedded into the environment, is driving a convergence of the physical and digital worlds promising to make our lives more informed and convenient. Concepts and technologies related to this idea have been researched for over two decades under various names, including Ubiquitous Computing, Pervasive Computing, Ambient Intelligence (for a delineation of these terms see Ronzani, 2009) and more recently Internet of Things (Ashton, 2009). They all share the idea of augmenting the physical environment with digital information and services. One example of such augmentation is ubiquitous annotation, which involves attaching digital information to physical objects and places (Hansen, 2006).

Well known applications of ubiquitous annotation include mobile tourist guides that provide visitors with information about nearby attractions, location-based games where players hunt for virtual treasures in the physical world and heritage trails where people access information about points of interest on their mobile device via visual or radio frequency markers. While most of these systems deliver professionally produced content to consumers in a one-to-many communications model, some applications, drawing on successful social concepts from the World Wide Web, involve user-generated content in a many-to-many communications model.

Commercial examples of user-generated ubiquitous annotation include physical "Like" buttons1, where people express their preference for a local business by scanning a visual marker with their mobile device, and "Check-in" marks2, where people record their physical presence at a place by scanning a radio frequency tag or reporting their current location. Academic examples include research prototypes that enable users to attach provenance information to physical objects (Barthel et al., 2012), rate and recommend products in retail environments (Karpischek, Michahelles and Fleisch, 2012), communicate over time via place-based messages in urban environments (Seeburger, 2012) and annotate museum exhibits (Hsu and Liao, 2011; Gray et al., 2012).

However, while applications of ubiquitous annotation are rapidly evolving from content consumption, involving the delivery of mostly static, professionally created information, to content "prosumption" (Toffler, 1980; Ritzer, 2010) or "produsage" (Bruns, 2006, 2008), involving the production and consumption of dynamic user-generated content, the user experience for accessing ubiquitous annotation has essentially stayed the same.

For location-based annotations, users typically start an application on their mobile device and activate a discovery mode to find points of interest, which then can be selected to call up additional information. Importantly, users initiate the process of information discovery.

---

and access based on the assumption of digital annotations in their environment as there is no indication of them in the physical world.

For marker-based annotations, users typically start a reader application and scan the marker to access digital information. While the presence of markers in the physical environment strongly indicates the availability of digital content or services (at least to people recognising them), associated signage explaining interaction details or the type of content to expect is typically static, often insufficient and sometimes non-existent. Users again initiate interaction based on partial information without knowing whether the marker works as expected and whether it leads to content that justifies their interaction.

In both cases, users carry out several interaction steps before they have access to up-to-date information, which could motivate and support their engagement in first place. This problem is particularly critical for user-generated content where users are interested in the amount and recency of contributions, which indicate the relevance of the annotated object and related discussion, and help users to make informed decisions about their potential engagement. Furthermore, when users create their own annotations and attach them to an object or place, there is no feedback to support their interaction and no trace in the physical environment once interaction has taken place.

User experience issues related to the invisibility of digital information and services are not limited to ubiquitous annotation but a common problem in pervasive service interaction. Critical voices have pointed out that many of these systems violate basic principles of human-computer interaction (HCI). Specific criticism is directed at the failure to provide adequate status information and feedback to users (Bellotti et al., 2002; Rehman, 2002, 2005), the loss of control by the user (Rehman, 2002, 2005; Barkhuus and Dey, 2003) and the absence of information that would allow users to form mental models about pervasive systems and help them to recover from errors (Bellotti et al., 2002; Vermeulen et al. 2009). In a professional context, these concerns are reflected in the "No to NoUI" movement (Arnall, 2013), which criticises invisible interfaces as "misleading, unhelpful and ultimately dishonest" (ibid) and argues that interfaces should instead be readable and understandable in order to build trust and confidence.

Empirical studies support this criticism. Research into users' perceptions, concerns and interaction with visual markers and radio frequency tags, two of today's most common technologies to anchor digital information in the physical world, has revealed a wide range of problems related to their usability and overall user experience. These include a lack of appropriate mental models (Mäkelä et al., 2007; Neil et al., 2007; Hardy et al., 2010a), a perceived lack of control (Riekki, Salminen and Alakärppä, 2006) and uncertainty about the security (ibid), integrity (Neil et al., 2007) and currency (Hardy et al., 2010a) of markers. Furthermore, research has identified low expectations of potential rewards as the main reason for user to not engage with markers (Russel, 2011; Aguirre, Johnston and Kohn, 2012).
There have been various research efforts to give users a better idea of what to expect before they interact with markers. With regard to visual markers, Costanza and Leinss (2006) explored the use of topology-based tags, which do not depend on actual marker geometry and therefore can be designed in an arbitrary fashion, to "tell a story by transforming the markers into sets of icons" (p.3). With regard to radio frequency markers, various designs have been explored for suitable iconography to advertise interaction points (Arnall, 2006) and guidelines have been developed to provide standardised information about supported interaction and the type of content users can expect (Riekki, Salminen and Alakärppä, 2006; Pyykkönen et al., 2012). These approaches involve static signage, which is economic to produce but cannot display dynamic content. While this is fine for immutable annotations, it is less well suited for dynamic, user-generated content that regularly changes and derives much of its appeal to potential users from the number and recency of contributions.

As for dynamic information display, Rehman, Stajano and Coulouris (2005) used Augmented Reality (AR) and Head Mounted Displays (HMDs) to overlay information about user choices and system feedback onto the physical world in which pervasive systems are integrated. Similarly, Vermeulen et al. (2009) used animated projections to overlay visualisations of system components and processes onto the physical world to help users diagnose and cope with errors in pervasive systems. These approaches are interesting from a technological point of view but they are unsuitable for uses outside the laboratory: people don't usually wear HMDs in day-to-day situations while back-projections are impractical in most cases due to space requirements and front-projections are easily obscured. Considering these drawbacks, Bellotti et al. (2002) note that ideally augmented objects themselves should be capable of displaying dynamic information about their state.

The research picks up this idea and links it to Weiser's (1994) call for "many, many displays", which he envisioned as small, cheap, low-power, "electronic postit [sic] notes stuck to things". It appropriates Weiser's original idea of generic "throw-away displays" (ibid) that can be easily configured, deployed and re-used, and frames it in the specific application context of ubiquitous social object annotation, where people create and consume digital annotations attached to physical objects and places and where dynamic metadata about user-generated content is an important motivator for engagement. Reflecting this application context, we call these displays Social Object Labels (SOLs).

![Figure 1: Generic Social Object Label (SOL) with dynamic display and trigger for mobile interaction.](image)
SOLs combine a small, typically inch-scaled (Weiser, 1991), display with a trigger to initiate mobile interaction (Figure 1). They augment physical objects and places with annotation and display capabilities. As SOLs can show dynamic, situated information before, during and after interaction, they have the capacity to improve the user experience of ubiquitous annotation over markers with static signage. How this capacity can be realised and shaped into specific implementations of SOLs that improve awareness, encourage engagement and enable users to access and create ubiquitous annotations with effectiveness, efficiency and satisfaction\(^1\) is the subject of this thesis.

1.2 Research focus

In a recent paper taking stock of Ubiquitous Computing (ubicomp) research and discussing how the field can develop from here, Abowd (2012) argues that ubicomp technologies and infrastructure are now so common that they no longer require special attention, leading to actual ubicomp research becoming a niche topic while the broader field moves on to applications research exploring possible uses of ubicomp technologies to address problems in a wide range of domains.

On the surface, this also applies to the research described in this thesis, which explores the use of ubicomp technologies for social object annotation (the application) in museums (the domain). However, as the research pivots on the use of small pervasive displays as a means to provide situated, human-readable information about digital annotations in the physical world, it is not purely applications research but has a distinct ubicomp research aspect. Inch-scale pervasive displays have only recently been pointed out as an example of Weiser's (1991) predictions that are "less common" (Dix and Sas, 2011) or did not come true in the envisioned form as cheap, low-powered, impersonal devices (Abowd, 2012). While there is a large body of research on engagement and interaction with large and medium-sized pervasive displays, there is little research focusing on small pervasive displays, in particular in the context of supporting ubicomp research aspect.

Based on these considerations, the research has both ubicomp and applications aspects. Furthermore, as design research is contextual by nature, solving a particular problem under a particular set of circumstances (Saffer, 2010), it also investigates domain-specific aspects that add context and detail to the problem:

- From a ubicomp perspective, the research looks at SOLs as a specific manifestation of small, interactive, pervasive displays. It defines, structures and explores the design space for SOLs with a view to situating them in relation to similar display concepts and generating empirically validated design principles.
- From an applications perspective, the research investigates how SOLs can support ubicomp research aspect.

generation and consumption with a view to creating a satisfying experience for users and supporting administration and moderation by host-organisations.

- From a domain perspective, the research explores SOLs as a platform for audience engagement and social interpretation (Giannachi and Tolmie, 2012) in museums. It investigates the domain specific requirements and constraints for such a system from both visitor- and museums- perspectives.

The design of working SOL prototypes that can be deployed and evaluated in realistic target environments takes into consideration all three of these perspectives.

Reflecting its original motivation to address the problematic user experience of accessing ubiquitous annotations through physical markers (see 1.1), the research takes mobile interaction with SOLs as its starting point. This initial focus informs the early prototyping stages and manifests itself in all three research perspectives, ranging from problems around Physical Mobile Interaction (PMI) (Rukzio et al., 2006) in the ubicomp perspective to mobile-related engagement barriers and user control in the application perspective, and institutional framing such as Bring Your Own Device (BYOD) policies in the domain perspective.

1.3 Aims and objectives

The research aims for this thesis project are as follows:

RA1. Define and structure the design space for SOLs to inform its systematic exploration

RA2. Investigate visitors’ mental models of commenting and feedback in museums, and their implications for the design of SOLs in this domain

RA3. Develop design recommendations for SOLs in museums, including their integration with a mobile application and the environment, to inform future research efforts

Specific objectives towards these aims are:

RO1. Carry out a literature review to contextualise the research (RA1, RA2, RA3)

RO2. Analyse and synthesise design guidelines and taxonomies for related display concepts (RA1)

RO3. Distinguish SOLs from related display concepts and identify design aspects not sufficiently covered in existing guidelines and taxonomies (RA1)

RO4. Carry out a survey to investigate visitors’ mental models of commenting in museums and translate findings into requirements for SOLs (RA2, RA3)

RO5. Carry out design activities to analyse the requirements and preferences of museum professionals and potential users (RA3)

RO6. Iteratively develop SOL prototypes fit for deployment in museums (RA3)

RO7. Empirically evaluate SOL prototypes in a real museum context (RA3)

RO8. Synthesise findings from all research activities to formulate design recommendations for SOLs in museums (RA3)
1.4 Research questions

Research questions naturally emerge from the aims to define and structure a design space for SOLs, which have their own particular set of problems, to explore that design space in the context of commenting in museums, of which is little known from a visitor perspective, and to develop design recommendations for SOLs in that specific domain:

RQ1. How to define and structure the design space for SOLs?
   - How do SOLs relate to similar display concepts and what distinguishes them?
   - What are the salient design aspects of SOLs?

RQ2. How can SOLs support commenting in museums?
   - What are visitors' preferences and expectations for commenting?
   - How do these translate into requirements for SOLs?

RQ3. How should SOLs be designed and integrated with museum environments?
   - How to attract attention and encourage engagement?
   - How to support mobile interaction with SOLs?
   - How to balance interaction between mobile and SOL?
   - How to integrate SOLs with the physical, technical and information environment?

1.5 Contribution

The research makes three key contributions:

C1. A theory-driven design space analysis, synthesising relevant taxonomies and design heuristics for related display concepts and complementing them with aspects emerging from the design research. The resulting structure supports a systematic exploration of the design space of SOLs and similar display concepts.

C2. Audience research into visitors' preferences, expectations and mental models of commenting and feedback in museums. Findings fill a gap in the literature, which so far only offers museum perspectives on this aspect, and can inform the design of platforms and policies for user-generated content in museums.

C3. Empirically validated design recommendations for SOLs that can inform future research and development efforts. While the recommendations are developed in the context of social interpretation in museums, many of them are equally relevant to other applications and environments involving pervasive displays that support mobile interaction and are driven by user-generated content.

Acknowledging that the design space (C1) and related recommendations (C3) developed in this thesis are the result of a single research effort and therefore necessarily limited in both perspective and reach, the title of this thesis references "A design space" rather than "The design space". This more tentative formulation leaves it to future research efforts to complement and consolidate the design space for SOLs presented in this thesis.
1.6 Thesis overview

This thesis is structured into ten chapters, including this introduction:

Chapter 2 presents a literature review to situate the research in the wider field and relate it to relevant work from ubicomp, applications and domain perspectives. From a ubicomp perspective, the review looks at previous research into ambient displays, pervasive displays and physical mobile interaction with a view to identify critical design aspects for SOLs and provide guidance on how to address them. From an application perspective, the review touches on the theoretical underpinnings of social object annotation and looks at relevant aspects of collecting and handling user-generated content. From a domain perspective, the review looks at previous efforts involving social object annotation and interpretation in museums and identifies commonly used approaches to profiling and segmenting audiences. Complementing these three design perspectives, the review also looks at methodological aspects of researching ubicomp technologies in general and challenges related to measuring peripheral awareness and interaction with ambient and pervasive displays in particular.

Chapter 3 discusses the methodology of the research. It explains the choice of Design Research (March and Smith, 1995; Edelson, 2002; Vaishnavi and Kuechler, 2009) as a methodological framework and discusses specific approaches and methods used in the design and evaluation studies. The chapter also provides an overview of the main participant groups involved at various stages and discusses ethical considerations.

Chapter 4 presents a systematic design space analysis that distinguishes SOLs from other display concepts and identifies their salient design aspects. It covers two temporally separate stages, first analysing and synthesising taxonomies, design heuristics and design space analyses for related display types to identify design aspects from the literature, and then complementing these post-hoc with design aspects emerging from the iterative design research. The chapter then consolidates the resulting set of design aspects into a design space structure comprising ten high-level aspects and discusses tensions between them before concluding with a discussion of findings with respect to related research questions.

Chapter 5 reports on a survey exploring visitors' mental models, expectations and preferences for commenting and feedback in museums. It describes the methodology of the survey, involving 104 structured visitor interviews at three museums, and presents findings on salient aspects ranging from preferences for commenting mechanisms to IP ownership and control over comments. The chapter concludes by relating findings to research questions and discussing their wider impact.

Chapters 6 to 8 describe key studies in the design and development process, including user and scenario modelling, expert interviews with museum professionals and prototype design and evaluation. The latter encompass early prototype development, formative user-testing and co-design with potential users, and two field trials of SOL prototypes in real exhibition
environments. Each of these chapters discusses the rationale, methodology, findings, limitations and conclusions from the study they describe.

Chapter 9 pulls together findings from all research activities, including the design space analysis, literature review, museum visitor survey and the design and evaluation studies described in the preceding chapters to formulate design recommendations. It is structured after the design space structure developed in Chapter 4 and provides recommendations, supporting evidence and implementation examples for each design aspect.

Chapter 10 presents conclusions. It reviews how the research meets the stated aims and objectives, summarises findings with reference to the research questions, restates the contribution and sets out future work.

1.7 Timeline of research activities

1. Literature review (Chapter 2): covering the whole research, with an initial reviewing period followed by additional reading throughout.
2. Design space analysis (Chapter 4): first stage informed by literature, second stage informed by aspects emerging from research activities.
3. Museum visitor survey (Chapter 5): carried out during early stages of the research, informing the visitor and scenario modelling as well as the early prototype design.
4. Visitor and scenario modelling (Chapter 6): initial development of personas and scenarios, refined and extended based on findings from expert interviews, user testing and field trials.
5. Expert interviews (Chapter 7): spread over a long period involving prototype versions 4 to 6.
6. Early prototyping (Chapter 8.2): design and development of low-fidelity prototypes versions 1 to 3, leading up to first high-fidelity prototype version 4.
7. Field trial 1: Fail Better (Chapter 8.3): evaluate prototype version 5 in an authentic gallery environment.
8. User testing and co-design (Chapter 8.4): with potential target users, involving prototype version 6.
9. Field trial 2: Home\Sick (Chapter 8.5): evaluate prototype version 7 in an authentic gallery environment.
10. Design recommendations (Chapter 9): synthesise findings from all research activities.

Figure 2: Timeline of research activities

The order of chapters in this thesis does not always reflect the chronological order of related research activities (Figure 2). For instance, the design space analysis (Chapter 4) was
carried out in two separate stages at the beginning and end of the research but is presented as one single chapter developing a design space structure, while the early prototype development (Chapter 8.2) started before the museum visitor survey (Chapter 5), scenario development (Chapter 6) and expert interviews (Chapter 7) but is presented together with other design and evaluation activities in the iterative development of SOL prototypes from version 1 to 7.

1.8 Terminology

This section briefly clarifies key terms used throughout this thesis. Its sole purpose is to contextualise and delineate these terms and justify their use in this thesis. No attempt is made to provide general definitions that would be valid in a wider context.

In alphabetical order:

Co-design

The term co-design is used in this thesis in reference to activities described in in Chapter 8.4, where potential users are involved in the design of a subsequent iteration of SOLs by discussing their preferences for design alternatives and drawing their own designs on paper. Co-design in this context does not refer to a specific methodology but is based on Sanders and Stappers' (2008) more general notion of co-design as "designers and people not trained in design working together in the design development process" (ibid, p.6).

Display

In order to not prematurely limit the design space for SOLs and ensure that the research can take full advantage of the large body of literature on ambient displays, which explicitly include "non-display displays" (Weiser, 1994), the term display is used in the broadest possible sense in this thesis, particularly in the literature review and design space analysis, to include visual, audio, kinetic and olfactory displays or combinations thereof.

Museum

Following Falk and Dierking (2000), the generic term museum is used throughout this thesis to describe a wide range of institutions that present objects (in the broadest sense) to visitors in public or semi-public settings for the purpose of edification and education. This includes "art, history, and natural museums; science centers; historic homes; living history farms and forts; aquariums; zoos; arboretums; botanical gardens; and nature centers [sic]" (ibid, p.xi) as well as public galleries, public sculpture, memorials and historic buildings and places. In some cases, the terms "gallery" and "exhibition space" are used instead to emphasise the specific context of a curated environment, which typically has associated rules (e.g. no photography) and social protocols (e.g. not to talk loudly) that influence how visitors interact with exhibits, SOLs and each other.
**PMI (Physical Mobile Interaction)**

The acronym PMI stands for Physical Mobile Interaction and is used extensively in the literature exploring the various ways how people can interact with physical objects and places via their mobile phone (e.g. Broll, 2006; Rukzio et al., 2006; Herting and Broll, 2008; Seewoonauth et al., 2009; Hardy, 2010a; Möller et al., 2012). In the context of this thesis PMI is used in reference to the aspect of connecting a mobile device to a SOL, for instance by touching an NFC tag or scanning a QR code.

**Requirements, Guidelines, Findings, Recommendations**

The literature on Requirements Engineering typically distinguishes between functional and non-functional requirements, with the former describing specific system behaviours and the latter overall qualities or attributes of a system. As pointed out in Cremers and Alda (2006), there is no clear distinction between the two, as requirements often can be expressed as both functional or non-functional requirements, depending on the level of detail and the perspective of the analyst. Similarly, there is no clear distinction between non-functional requirements and design guidelines, which also depends on how they are expressed and which level of detail they include. For instance, the statement "The system should streamline engagement and avoid interruptions" could be both a non-functional requirement and a design guideline. Acknowledging this ambiguity and aiming for simplicity of expression, this thesis uses the more abstract and research-oriented term *finding* for requirements, design guidelines, user preferences and general insights emerging from the literature and research activities. It uses the term *recommendation* in Chapter 9 when referring to synthesised and generalised findings resulting from this research that might benefit future research and development.

**Social object annotation**

The defining aspect of *social object annotation* is that it is produced and consumed by “produsers” (Bruns, 2006; 2008) or “prosumers” (Toffler, 1980; Ritzer, 2010) in a many-to-many communication model rather than by professional content creators in a one-to-many model. While most commonly associated with written text, annotations in this thesis can encompass a wide range of media including text, images, tags, ratings and application-specific information such as check-ins⁴. They accumulate content from multiple users, which can lead to discussions (text), scores (check-ins) and averages (ratings).

**Ubicomp**

The research relates to Ubiquitous Computing, Pervasive Computing, Ambient Intelligence and the Internet of Things (IoT). Each of these terms has been in use for several years and is preferred by their respective research communities. While these concepts share by and

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large the same attributes (Ronzani, 2009), they appeared at different times, were promoted by different companies and have different emphases:

- Xerox introduced the term Ubiquitous Computing in 1991 to describe a vision of unobtrusive, human-centric computing taking advantage of the proliferation and diversification of computing devices and networks (Weiser, 1991).
- IBM coined the term Pervasive Computing in 1998 with an emphasis on integrating computers into our surroundings, primarily in the contexts of e-commerce, logistics and business processing (IBM, 1998).
- Phillips began using the term Ambient Intelligence in 1999 when referring to the integration of intelligent systems and devices into homes and offices (Aarts, Harwig and Schuurmans, 2001).
- The term Internet of Things was first used by Kevin Ashton from RFID Journal in 1999 to describe the concept of uniquely identifiable objects in the physical world that can communicate with each other and can be controlled via their virtual representation on the Internet (Ashton, 2009).

Despite the popularity of the term Internet of Things (Figure 3), we generally use the short form *ubicomp* for Ubiquitous Computing in this thesis due to its human-centric perspective, which resonates with the user-centred methodology and research perspective in this thesis. We sometimes use the terms *pervasive* or *ambient* to emphasise integration with the physical or cognitive environment, or when referring to research perspectives associated with them in the literature.

**Ubiquitous annotation**

Ubiquitous annotation involves attaching digital information to physical objects and places (Hansen, 2006). Attaching information to an object or place increases its spatial deixis (ibid), eliminating the need to describe the object itself and giving it a context specific meaning. Hansen (2006) proposes a taxonomy for presenting ubiquitous annotation based
on the context in which annotations are experienced and the spatial relationship between object and annotation (Table 1).

<table>
<thead>
<tr>
<th>Attached</th>
<th>Detached</th>
</tr>
</thead>
<tbody>
<tr>
<td>On Location</td>
<td>Annotation presented on object (e.g. Augmented Reality)</td>
</tr>
<tr>
<td>Off Location</td>
<td>Annotation presented on representation of object (e.g. Virtual Reality)</td>
</tr>
</tbody>
</table>

Table 1: Hansen’s (2006) two-dimensional taxonomy for presenting ubiquitous annotations

User-centred design

The term user-centred design is used throughout the thesis to emphasise an approach where users influence how a design takes shape. This understanding is based on the much-cited definition by Abras, Maloney-Krichmar and Preece (2004). The authors acknowledge that there is a spectrum of ways in which users are involved in user-centred design, ranging from well-defined methods in which users are involved as partners and have a deep impact on designs, to more loosely defined approaches where users are involved at specific stages in the design process such as requirements gathering and usability testing. In the context of this thesis the term user-centred design aligns more with the latter end of this spectrum rather than referring to any specific user-centred design methodology.
Chapter 2 Literature Review

2 Literature Review

2.1 Introduction

2.1.1 Aims of the review

The aims of this literature review are threefold. Firstly, it seeks to contextualise the research by identifying relevant literature and discussing where it can build on previous efforts or offer alternative viewpoints. Secondly, it seeks to inform the design of SOLs by extracting requirements and heuristics from the literature, which may either be explicit in discussions of user needs and design guidelines or implicit in the discussion of research findings. Thirdly, it seeks to inform the research methodology by identifying appropriate approaches and methods for evaluating ubicomp applications.

Findings from the literature, such as requirements and heuristics that can inform the SOL design, are identified on the spot to make it easier for the reader to contextualise them. They are shown in grey boxes inserted into the main text and numbered in the form [FLn]:

FLO: Findings from the literature are shown in grey boxes

These findings from the literature are typically expressed as single sentence insights, despite some obvious shortcomings of this format:

1. They give no indication of the importance and specificity of insights, which range from high-level and general such as "FL42: SOLs should not distract visitors or divert their attention from exhibits" to specific and detailed, such as "FL38: SOLs should use clear, large fonts and appropriate white space to make them easy to read". Where appropriate, these qualitative differences, as well as potential tensions between insights, are discussed in chapter summaries.

2. They sometimes oversimplify findings by implicitly focusing on the particular use context of encountering SOLs in a gallery space. For instance, "FL47: SOLs should not require users to install a custom application" applies to that specific situation, ignoring that it might be entirely appropriate to ask visitors to install a custom application in other contexts, e.g. in the pre-visit phase in Brown and Ratzkin's (2011) Arc of Engagement when visitors plan their museum visit.

The main advantage of the single sentence format, and the reason why it is employed here and in following chapters, is that it helps to focus on specific aspects in research findings that are most relevant in the context of this thesis project and allows for more targeted referencing of these aspects in support of design recommendations in Chapter 9.

The next sections in this introduction briefly discuss the four perspectives reflected in the overall structure of the review.
2.1.2 Perspectives on the problem space

The review is structured broadly after the three research perspectives discussed in the introduction to this thesis (see 1.2), including a ubicomp perspective concerned with small pervasive displays, an applications perspective concerned with social ubiquitous annotation and a domain perspective concerned with audience engagement in museums. In addition to these three perspectives, the review includes a forth perspective concerned with methodology for the evaluation of ubicomp technologies.

Ubicomp perspective
From a ubicomp perspective, the review includes literature related to the display and mobile interaction elements of SOLs. It looks at previous research into ambient displays, pervasive displays and public incidental use systems, focusing in particular on awareness models and the design tension between advertising information and interactivity on the one hand while minimising cognitive costs for users on the other hand. The review also looks at previous research into physical mobile interaction, focusing on technologies and interaction types as well as usability, trust and overall user experience.

Applications perspective
From an applications perspective, the review includes literature related to ubiquitous annotation and social object annotation. It looks at authoring systems enabling users to annotate the physical world and reviews previous efforts to address key problems in ubiquitous annotation such as object identification and information presentation. With regard to social object annotation and content prosumption (Toffler, 1980; Ritzer, 2010), the review looks at the theory behind these concepts, identifies various content and rating types and discusses practical issues related to user-generated content such as moderation and intellectual property.

Domain perspective
From a domain perspective, the review includes literature on informal learning, visitor engagement, interpretive labels and the use of interpretive technologies in curated exhibition environments. It explores how SOLs fit with museums’ educational objectives and how they can support participation and social interpretation in the gallery space without distracting from exhibits or disturbing visitors seeking a more contemplative museum experience. It also reviews previous research into social object annotation and looks at the challenges of user-generated content in a museum context with a view to informing the requirements analysis.

Methodology perspective
From a methodology perspective, the review includes HCI and ubicomp literature focusing on methodological aspects. It looks at efforts to harmonise methods and metrics for the evaluation of ubicomp technologies and discusses the trade-off between evaluating
ubicomp technologies in the field and in the laboratory. The review also identifies particular challenges of evaluating pervasive displays and recommended approaches to address them.

The following sections discuss each of these perspectives in turn. Overall findings from the literature are discussed in the conclusions of this chapter.

2.2 Ubicomp perspective

2.2.1 Display taxonomies and design guidelines

A key aspect of this thesis is to situate SOLs with reference to similar display concepts described in the literature and to define and structure their design space. One way of approaching this is to look at existing taxonomies, design space analyses and design heuristics for related display concepts such as ambient displays and interactive public displays. This section identifies and briefly discusses relevant materials in the literature. A more detailed discussion is provided in Chapter 4: Design space analysis.

2.2.1.1 Ambient displays

Reflecting the diversity of designs and the complexity of design goals for ambient displays, the literature describes many efforts to categorise and structure the field and to formulate design heuristics that might be helpful to other research and development efforts. The following paragraphs briefly discuss the most important efforts in this line in chronological order.

Ames and Dey (2002) propose eleven design dimensions and related recommendations for ambient displays based on their experience in building and evaluating ambient displays and their expectations for their future use. The authors use their taxonomy to classify a range of ambient displays described in the literature.

Mankoff et al. (2003) formulate ten design heuristics for ambient displays with the aim of adapting Nielsen and Molich's (1990) heuristic evaluation as a discount evaluation technique for ambient displays. Originally based on Nielsen's (1994a) list of ten usability heuristics, the authors swapped out heuristics clearly aimed at task-oriented desktop systems and in their place introduced heuristics more relevant to ambient displays. The resulting design heuristics were refined over two iterations based on the development of two ambient displays.

Brewer (2004) proposes a nine-dimensional taxonomy of ambient displays focusing in particular on the information to be displayed. Based on the idea that ambient displays should be site-specific, which by extension determines the information to be displayed, design dimensions take the form of questions relating to the site and displayed information.

Pousman and Stasko (2006) developed a widely cited taxonomy for ambient information systems based on the four dimensions Information Capacity, Notification Level, Representational Fidelity and Aesthetic Emphasis. Using this taxonomy to categorise a wide range of ambient displays described in the literature, the authors (ibid) identified clusters of
systems along each design dimension, resulting in four archetypes of ambient displays, including Symbolic Sculptural Displays, Multiple Information Consolidators, Information Monitor Displays and High Throughput Textual Displays. Not surprisingly, SOLs do not fit any of these archetypes as they have a different purpose and use context from classic ambient displays which rarely support direct user interaction (Matthews et al., 2003). However, the underlying taxonomy includes useful dimensions that can help to structure the design space for SOLs.

Tomitsch et al. (2007) propose a nine-dimensional taxonomy and related metrics for ambient information systems. Proposed design dimensions include Abstraction Level, Transition Speed, Notification Level, Temporal Gradient, Representation, Modality, Source, Location and Dynamic of Input. While suffering from overlaps and ambiguities in both dimensions and metrics, the taxonomy includes important aspects related to the integration of displays with a specific use context (Source) and target environment (Location).

2.2.1.2 Interactive public displays

With regard to interactive public displays, the following paragraphs briefly discuss a range of design space analyses and taxonomies in chronological order.

With a view to examine user interactions and deployment issues in the context of people increasingly using their mobile device to interact with large public displays, Ballagas et al. (2004) propose eleven design considerations specific to mobile interaction with large public displays. Given their focus on mobile interaction, these are particularly relevant for SOLs, which only provide sparse information and escalate interaction to users' mobile device.

Mueller et al. (2010) provide a design space analysis of interaction with large public displays and related taxonomy with three primary dimensions. These include users’ mental models supported by the display, the interaction modalities supported by the display, and whether they support implicit or explicit interaction. Further dimensions such as single or multi-user support and the distinction between private, semi-public and public displays are not included in the taxonomy as they are deemed application- rather than interaction-centric.

Dix and Sas (2011) provide a design space analysis for interactive public displays discussing a range of aspects including the interaction with a personal device, the size and placement of the display, the impact of movement and contact on the interaction, and social aspects of the interaction. The authors go on to use the design space analysis as a framework to discuss design implications and strategies for mobile interaction with public displays.

Memarovic et al. (2013) group design challenges for community-supporting public displays into five layers including hardware, system architecture, content, system interaction and community interaction design, which together make up the P-Layers framework. The authors discuss individual aspects in each layer based on their experience in developing and deploying systems in authentic settings.
2.2.1.3 Summary

The review found a useful range of taxonomies, design space analyses and design heuristics for ambient displays and interactive public displays. While not discussed in great detail at this stage, it is obvious that this work can help to define and structure the design space for SOLs, which share many characteristics with ambient displays and interactive public displays. An in-depth analysis of individual design dimensions in the identified work and their relevance for SOLs is provided in Chapter 4: Design space analysis.

2.2.2 Awareness and engagement

SOLs are peripheral displays in that they are not meant to distract attention from the physical object or place they relate to. They are also access points for the related pervasive service enabling users to browse digital annotations and add their own. This dual functionality as peripheral display on the one hand and interaction gateway on the other hand creates a fundamental design tension in SOLs between being inconspicuous enough to not draw too much attention while being conspicuous enough to be perceived by passers-by and encourage interaction.

How can these contrasting design goals be met? How do people perceive displays in their environment? Are there ways to get users' attention without monopolising their cognitive resources? How can the transition from perception to engagement be supported?

Research into ambient displays, public and pervasive displays and incidental use systems has explored many of these questions and can provide useful pointers for the design of SOLs.

2.2.2.1 Peripheral attention and engagement

Research into ambient displays, a particular class of pervasive displays that "require minimal attention and cognitive effort and are thus more easily integrated into a persistent physical space" (Abowd and Mynatt, 2002), offers interesting insights into peripheral awareness and attention that is particularly relevant for SOLs with regard to their design goal of being unobtrusive and not unduly distracting attention from the object or place they relate to.

Ambient displays and related concepts such as peripheral displays (Matthews et al., 2003), glanceable displays (Matthews, Forlizzi and Rohrbach, 2006) and ambient information systems (Hazlewood and Coyle, 2009) are strongly influenced by Weiser and Seely Brown's (1996) vision of calm computing that leverages peripheral attention in an effort to minimise the cognitive costs of monitoring information.

Hazlewood and Coyle (2009) break down a user's field of perception into primary, secondary and tertiary realms of attention. Primary attention is focused on a specific task and object (e.g. word processor). Secondary attention enables users to perceive peripheral information (e.g. notifications on screen) while tertiary attention is tuned to environmental...
cues (e.g. voices next door). The authors suggest that ambient technologies should address, and switch between, these realms of attention (e.g. when a notification requires action).

There are numerous examples of ambient displays exploring aesthetically pleasing, non-intrusive ways of bringing information to the user's peripheral attention. The most common approaches include targeting non-visual modalities, representing information in abstract and artistic ways and using alternative interaction modes.


With regard to abstract and artistic information representations, some of the best-known ambient displays use aesthetically pleasing designs to blend into the environment. Hello.Wall (Prante et al., 2003) is a wall-sized ambient display that visualises information reflecting the identity and distance of people passing by via light patterns. Ambient Orb (2012) is a frosted glass sphere that changes its colour to visualise data. InfoCanvas (Stasko et al., 2005) is an electronic painting in which elements change appearance to represent changes in the monitored information. Dangling String, cited in Weiser and Seely Brown's (1996) original paper on calm technology, involves a piece of string hanging from the ceiling that is driven by a small electric motor to visualise network traffic.

With regard to alternative interaction modes, the literature describes several efforts including StaTube (Hausen et al., 2012), a tangible presence indicator and management system for instant messaging systems, FireFlies (Bakker, Hove and Eggen, 2013), ambient displays for classrooms that come with a wearable controller for teachers, and a prototype supporting tangible peripheral interaction in the office (Edge and Blackwell, 2009).

While pragmatic considerations concerning technical constraints, social acceptability in the target environment and production costs, especially when deployed in large numbers, limit actual designs, the variety in these examples points to a large design space for SOLs.

### 2.2.2.2 Focused attention and engagement

In contrast to ambient displays, research into public displays is not encumbered by an aspiration to be subtle and minimise users’ overall cognitive load. An important question in this field is how to attract the attention of audiences and, for interactive displays, how to communicate interactivity and encourage engagement.

With regard to attention, a large-scale empirical study by Huang, Koster and Borchers (2008) found that, contrary to their often assumed eye-catching and appealing qualities, public displays often have difficulties in attracting and holding people's attention. Given that public displays often show advertisement, Müller et al. (2009) use the term *Display Blindness* to describe this phenomenon and relate it to the *Banner Blindness* (Benway, 1998) observed on the Web, where people have such low expectations of advertisement banners that they automatically blank them out. A recent eye-tracking study in a retail
environment (Dalton, Collins and Marshall, 2015) supports this interpretation. It showed that while many participants looked at displays, fixations typically lasted only fractions of a second, indicating that they were reflexive rather than intentional.

Huang, Koster and Borchers' (2008) findings include interesting clues that can inform measures to overcome display blindness:

- Viewers spend only a few seconds to determine whether a display is of interest
- The positioning of displays is more important than the content
- Displays positioned at eye-height attract more attention
- Displays next to other eye-catching objects receive more attention
  (Huang, Koster and Borchers, 2008)

While these findings are based on large, non-interactive displays and cannot be applied indiscriminately to small, interactive displays, some aspects can be expected to equally hold for SOLs. In particular the observations that viewers only spend a few seconds to decide whether a display is of interest and that positioning is more important than content both offer interesting insights for SOLs. Other findings are more problematic. Installing displays at eye-height possibly conflicts with SOLs' design goal of being unobtrusive and might not comply with design conventions in the target environment, while installing displays next to eye-catching objects is overwritten by the need to install SOLs close to the object they relate to for users to understand their connection.

For interactive displays, attracting the audience's attention is only the first in a sequence of steps leading up to users' engagement and eventual disengagement. The literature offers several models of engagement with public displays, which have been classified by Michelis and Müller (2011) into ad-hoc models that describe how displays react to users, and observational models that describe how visitors engage with displays. Ad-hoc models use concepts of proxemic interaction (Greenberg, 2011; Wang, Boring and Greenberg, 2012) and they are typically employed to support specific stages in observational engagement models such as attracting attention and communicating interactivity.

One of the best known observational models of engagement with interactive public displays is the audience funnel (Michelis and Müller, 2011), which differentiates between six distinct phases including (i) passing by, (ii) viewing and reacting, (iii) subtle interaction, (iv) direct interaction, (v) multiple interaction and (vi) follow-up action. While this model primarily aims to quantify interaction with public displays, rather than to provide insights on how to encourage interaction, an earlier observational model by Brignull and Rogers (2003) describes three levels of interaction and offers advice how to help users transition between these stages:

1. Peripheral awareness: People are aware of the display but don't know much about it. To support users crossing from peripheral awareness to focal awareness, information should be glanceable and presented in a simple and attractive way.
2. Focal awareness: People talk about the display, watch it and learn about it. To support users crossing from focal awareness to direct interaction, there should be enough space around the display in which interaction can take place and the interaction should be easy to understand.

3. Direct interaction: An individual or group directly interact with the display

(Brignull and Rogers, 2003)

Another, more detailed model of engagement is presented by Finke et al. (2008). Originally developed for game design on large public displays, the authors define seven interaction states that cover the entire process of engagement. For each stage they discuss relevant design aspects:

1. Enter: Importance of environment and display position
2. Glance: Key information must be easy to read
3. Decode: Meaning and interaction must be easy to understand
4. Observe: Design should consider spectators' view (exploit honeypot effect)
5. Input: Design for ease of use and minimise social embarrassment
6. Feedback: Provide prompt feedback, compensate for network latency
7. Result: Results should be visible to user and bystanders

(Finke et al., 2008)

Despite being developed for a very different display concept and use context, many of these guidelines are relevant for SOLs. As they are informed throughout by literature, they often resonate with findings in other research and provide a comprehensive view on knowledge in this field.

Apart from interaction models and frameworks, the literature also offers general advice on how to advertise and encourage interaction with public displays. Based on a literature review of techniques used to communicate interactivity for public displays and tabletops, Müller et al. (2012) identified six factors influencing user engagement:

1. Displaying a call-to-action or simple static label such as “touch screen to begin”
2. Playing an attract sequence, e.g. slideshow or video explaining the interaction
3. Nearby analogue signage with simple call-to-action or a more complex manual
4. Honeypot effect: people are attracted by persons already interacting with a device
5. Persons inviting passers-by to interact
6. Prior knowledge that a device is interactive

(Müller et al., 2012)

While some of these techniques are not easily applicable to SOLs because they conflict with other design goals (2), are difficult to control (4) or require additional human resources (5),
they nonetheless offer a useful repertoire of measures to advertise interactivity and encourage engagement.

Casting the net even wider, many of the recommendations for interactive public displays resonate with the concept of "immediate usability" developed by Kules et al. (2004) to promote engagement with interactive kiosks. Kules et al.'s (ibid) guidelines are structured after Kearsley's (1994) four stages of user interaction with public access systems:

1. Immediate Attraction: use the most attractive content to demonstrate the system, play an attract sequence and clearly indicate how to begin using the system.
2. Immediate Learning: use the simplest practical interface, an immediately understandable metaphor and take advantage of common knowledge.
3. Immediate Engagement: encourage immediate interaction, provide immediate reward and avoid logins or other interactions that interrupt the user.
4. Immediate Disengagement: when a user departs, immediately reset the system and prepare for the next visitor.

(Kules et al., 2004)

While these guidelines were developed specifically for kiosks and similar public access systems and imply single-user, focused interaction, their relevance for SOLs lies in the strong emphasis on leveraging the small window of opportunity presented when users first notice and engage with the display.

2.2.2.3 Summary

Together, the recommendations and models of engagement discussed in this section provide valuable insights for the design of SOLs and their integration with the target environment. The following paragraphs synthesises key aspects discussed above into a set of findings from the literature.

The need to cater for users at different stages of attention and engagement is common to all models of engagement discussed above (Kules et al., 2004; Brignull and Rogers, 2008; Finke et al., 2008), and is further supported by Hazlewood and Coyle's (2009) call for ambient technologies to support, and be able to switch between, users' primary, secondary and tertiary realms attention.

FL1: The display should address all levels of attention and stages of engagement

Guidelines for Finke et al.'s (2008) Glance stage resonate with Brignull and Rogers' (2003) advice that glanceable information should be presented in a simple and "easy to pick up" way and with Kules et al.'s (2004) concept of Immediate Attraction, which suggests to use the most attractive content upfront. They are also supported by Huang, Koster and
Borchers' (2008) finding that viewers spend only a few seconds to determine whether a display is of interest.

**FL2:** Key information on the display should be quick and easy to read

Considerations relating to Finke et al.'s (2008) Decode, Observe and Input stages are in line with Brignull and Rogers' (2008) recommendations that interaction should be easy to understand in order to support users crossing from focal awareness to direct interaction, and can be linked to Kules et al.'s (2004) concept of Immediate Learning, which calls for a the simplest practical interface with an immediately understandable metaphor and advises to take advantage of common knowledge.

**FL3:** Interaction with the display should be easy to understand

Brignull and Rogers' (2008) recommendation that interaction should be lightweight to support users crossing from focal awareness to direct interaction resonates with Kules et al.'s (2004) concept of Immediate Engagement, which calls for a streamlined experience avoiding interruptions like login-, consent- and instruction screens.

**FL4:** The system should streamline engagement and avoid interruptions

Advice to not only consider active users but also bystanders in Finke et al.'s (2008) Observe and Result stages is further supported by Müller et al.'s (2012) finding that persons interacting with the display are rarely on their own. This aspect is especially relevant in the specific use context for SOLs explored in this thesis as audience research for museums consistently shows that more than half of all museum visitors come in groups of two or more people (e.g. Creative Research, 2005).

**FL5:** The display should support multi-user interaction

The need for prompt feedback in Finke et al.'s (2008) Feedback stage is further supported by evidence that even small delays between action and feedback can destroy the perception of causality when interacting with a system (Scholl and Tremoulet, 2000).

**FL6:** The display should provide prompt interaction feedback

The consideration of social embarrassment in Finke et al.'s (2008) Input stage are further supported by Brignull and Rogers (2003), who found that potential social embarrassment is the main reason for many people not to engage with public interactive displays, and by Riekki, Salminen and Alakärppä (2006), who found that many users feel embarrassed to reach out and interact with NFC tags in public spaces.
In summary, this section has synthesised recommendations in the literature into a set of findings relating to awareness and engagement. Recurring themes include the need to design for all stages of attention and interaction, to present information in a quick and easy to understand way, to streamline engagement by removing potential barriers and avoiding interruptions, to consider groups of users and bystanders in the design and to ensure that interaction is intuitive, easy to learn, responsive and not embarrassing.

2.2.3 Physical mobile interaction
This section looks at technologies for identifying and interacting with physical objects and places. It reviews literature on the affordances, usability and overall user experience of these technologies. Reflecting the ubiquity of smartphones on the one hand, and the fundamental requirement for public interactive displays to be accessible for as broad an audience as possible, it focuses in particular on technologies that support interaction with a mobile device, also referred to as Physical Mobile Interaction (PMI) (Rukzio et al., 2006).

2.2.3.1 Introduction
The most common form of PMI involves single tag interaction which is used in various contexts such as ticketing, access control and entertainment. Single tag interaction typically reduces various steps in traditional screen-based interaction, such as accessing a website, navigating to a page, selecting a specific option etc., into the single step of touching a tag. The resulting directness and simplicity are seen as the biggest advantages of single tag interaction (Herting and Broll, 2008).

Multi tag interaction, which maps different functionality of an application to different tags dramatically increases the potential of PMI and allows the construction of complex physical user interfaces. Examples of multi tag user interfaces include interactive posters and maps (Broll et al., 2007; Broll and Hausen, 2010), office automation systems (Riekkilä, Salminen and Alakärppä, 2006) and multimedia players (Pyykkönen et al., 2012).

Hardy et al. (2010a) classify physical interfaces along the dimensions display feedback (static, dynamic) and tag coverage (single tag, multiple tags, tag grid), resulting in six basic categories of PMI. Most research into PMI so far has focused on interfaces with static displays such as stickers, leaflets, posters and maps (Riekkilä, Salminen and Alakärppä, 2006; Broll et al., 2007; Neil et al., 2007; Mäkelä et al., 2007; Rukzio et al., 2007; Broll and Hausen, 2010; Hardy et al., 2010b). The literature offers only few examples where PMI has been researched with dynamic displays, and all of these involve tag grids as opposed to single or multiple tags.

Seewoornauth et al. (2009) combine tag grids with LCD screens to explore interaction patterns for exchanging data between mobile and personal computer. Hardy et al. (2010a) combine tag grids with dynamic map projections to explore differences to user interaction
with static map displays. The authors (ibid) point out that dynamic displays have two distinct advantages over static displays. Firstly, as feedback is provided directly on the dynamic display, there is no need to shift attention between physical display and mobile device, maintaining the spatial awareness provided by the physical display. Secondly, dynamic displays do not require user interaction before they reveal up-to-date information, providing a degree of awareness not possible with static displays. This aspect seems to strengthen the key argument in this thesis that dynamic displays have potential to improve the user experience of PMI.

The literature on PMI provides strong arguments for combining tags with dynamic displays, and at the same time suggests that the only previous work with PMI and dynamic displays involves tag grids. By combining single tags with dynamic displays, the research breaks new ground and investigates a type of PMI that has been identified in the literature but not yet actively explored (Hardy et al., 2010a).

2.2.3.2 Object identification

One of the key challenges of ubiquitous annotation is the basic requirement to anchor digital information to a physical object or place (Hansen, 2006), which involves their unique identification in both the digital and physical worlds. Identification in a digital context involves an identifier, which can either be computed, based on the object’s intrinsic or extrinsic properties, or simply generated following a defined (and possibly standardised) scheme. Identification in a physical context involves reading or dynamically computing an object’s ID, usually using a mobile device.

Kindberg (2002) proposes the term "identifier resolution" to describe how physical resources are linked to digital resources. He specifies the following sub-tasks involved in ID resolution:

- ID creation or "minting": creating a unique ID
- Binding: linking an ID to a digital resource and to a physical object (tagging)
- ID capture: reading an ID in the physical world (usually with a mobile device)
- Conversion: converting raw identifiers into a globally unique identifier (GUID)
- Resolution: processing the GUID to produce the digital resource defined by its binding

(Kindberg, 2002)

This review is particularly interested in aspects of ID creation, physical binding and ID capture, all of which impact on the user experience of ubiquitous annotation. The difference between computed and generated IDs is critical in this context.

Examples of computed identifiers include an object’s visual signature based on a set of control points (i.e. image/object recognition) and an object's location based on its latitude, longitude and altitude. A key advantage of computed identifiers is that they are inherent to the object or place. As they can be computed dynamically, there is no need for physical
binding. A key drawback is that computed identifiers are not necessarily unique. Object recognition cannot distinguish between two objects that look the same and location-based identification breaks when the object is moved.

Assigned identifiers, by contrast, are truly unique but they need to be encoded and physically attached (bound) to an object or place. Assigned identifiers can be proprietary, in which case they are unique only within the system that issued them, or they can follow a standardised scheme such as Unique Resource Identifier (URI)\(^5\), Electronic Product Code (EPC)\(^6\) or Global Trade Item Number (GTIN)\(^7\), in which case they can be used across applications.

Kindberg (2002) identifies several requirements for identifiers:

- **Uniqueness:** IDs should be unique over space and time
- **Inexhaustible supply:** there should be enough IDs to tag an infinitely large number of objects
- **Legacy identifiers:** ID resolution should be able to work with legacy identifiers
- **Human tractability:** IDs should be human readable to enable users to react to errors
- **Convenience of minting:** IDs should be easy and cheap to produce

(Kindberg, 2002)

Some of these requirements are primarily of a technical nature relating to the scalability and efficiency of an identification and tagging system.

\[ \text{FL8: } \text{IDs should be unique, inexhaustible in supply and easy to produce} \]

The requirement for human readability clearly relates to usability aspects of a tagging system. While at first sight this creates a design tension with the requirement that tags should be quickly and reliably machine readable (see below), this aspect can be addressed by providing multiple alternative encodings of identifiers.

\[ \text{FL9: } \text{SOLs should provide alternative encodings of identifiers, including a human-readable encoding that enables users to react to errors.} \]

Physical binding and ID capture both involve markers or labels (tags) that identify the host object to which they are attached. In their early work on ubiquitous electronic tagging,

---


Fl10: Tags should support quick and reliable reading and tag readers should be of a reasonable size and cost.

Want and Russell (2000) point out that for day-to-day applications tags should support quick and reliable reading and tag readers should be of a reasonable size and cost.

Want and Russell (2000) distinguish between passive tags that require no internal power supply (e.g. barcodes, radio frequency tags) and active tags that do require their own power supply to operate (e.g. radio frequency or infrared beacons). This fundamental distinction is helpful with regard to integrating SOLs with the environment, where the need for a power supply is a key technical requirement.

2.2.3.3 Interaction models

From an HCI perspective, a key aspect of tagging technologies is the interaction they afford in Kindberg's (2002) *ID capture* subtask, i.e. when users try to read an object's ID with their mobile device. As PMI is a relatively new paradigm which many people are not yet familiar with, the user experience of this initial interaction step is crucial when trying to engage audiences. The literature describes various interaction models in this context.

Rukzio et al. (2007) identified touching, pointing and scanning as key interaction techniques and explores their qualities in empirical studies with users:

- **Touching a tag with the mobile device.** Works over short distances up to 10cm. Typically uses radio frequency identification or proximity sensors. Regarded by users as quick, unambiguous, simple and secure with very low error rates. Requires little cognitive load and is easy to learn due to its similarity to other physical interaction such as for instance pressing a button. Preferred when mobile device is in reach of the user, however, users are not always motivated enough to physically approach the tag (which is necessary for touch interaction).

- **Pointing the mobile device towards a tag.** Works over short and medium distances up to 10m. Typically uses visual markers, light beams or infrared sensors. Regarded as intuitive because it corresponds to deictic gestures. Speed and error rates depend on implementation. For instance, implementations using a laser pointer are seen as fast and simple, while implementations with visual markers are seen as cumbersome and error prone (however, marker recognition speed and accuracy has improved dramatically since the study was carried out). Requires more cognitive load than touching due to the need to correctly line up the mobile device with the object.

- **Scanning the environment to produce a list of nearby tags on the mobile device screen.** Works over short, medium and long distances up to 100m. Typically uses location or networking technologies. Seen by users as less intuitive because of its indirectness but also as requiring the least physical effort. Users have been
observed to switch to scanning in order to avoid physical effort related to touching and pointing. Users prefer scanning in some instances (e.g. mobile tourist guides) because the system proactively informs them of points of interest. High cognitive effort required to establish mapping between a list item on screen and the physical object.

(Based on Rukzio et al., 2007)

A fourth interaction technique identified in Rukzio et al. (2007) is user-mediated object interaction, where users read an ID, typically a number or Web address, and type it into the mobile phone. A recent study by Vepsäläinen et al. (2015) comparing URL input with NFC (touch), QR codes (point) and WiFi (scan) found this to be the most usable method for initiating the connection between a mobile device and public display. As this technique involves marking up the physical object with a human-readable ID, rather than technical tagging, it meets finding [FL9] that displayed IDs should include a human readable representation to enable users to react to errors.

Other interaction techniques discussed in the literature include Browsing (Välkkynen and Tuomisto, 2005) and Hovering (Välkkynen, 2006). While browsing describes the physical analogy to screen-based web-browsing via hyperlinks and technically falls back to Rukzio et al.'s (2007) touching, pointing and scanning as actual interaction models, hovering presents a special case of touching where a link is displayed on the mobile device but not yet activated, similar to hovering a mouse pointer over a hyperlink. This behaviour, however, is implementation-dependent and can in fact be achieved with any of the interaction techniques described above.

Overall, these findings suggest that while touching is the preferred interaction model in many aspects including intuitiveness, speed, error resilience and cognitive load, other interaction models, too, have their specific advantages. For instance, scanning involves less physical effort and is preferred in some situations where users are not motivated enough to physically approach an object for touch interaction; pointing in many aspects rivals touch interaction but strongly depends on the specific implementation; user-mediated interaction is less fluid but well understood by users and very reliable. A suitable approach with respect to broad engagement might therefore be to support multiple interaction models and provide users with choice rather than forcing them to use one specific model.

**FL11:** The display should support multiple alternative interaction models to cater for different contexts and user preferences

Regarding users’ expectations in specific application contexts, Geven et al. (2007) identified four common metaphors for PMI applications (Table 2), focusing specifically on radio frequency tags and therefore on the touch interaction paradigm discussed above. They offer valuable insights into users’ expectations regarding workflow and feedback.
<table>
<thead>
<tr>
<th>Metaphor</th>
<th>Description</th>
<th>User expectations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Barcode scanner</td>
<td>Reading from passive objects, e.g. reading a hyperlink on a poster</td>
<td>Users know there won’t be feedback on the poster and expect all interaction and feedback on the mobile</td>
</tr>
<tr>
<td>Paper ticket</td>
<td>Verification for services, e.g. read ticket for access control</td>
<td>Users expect feedback from the fixed terminal not the mobile device (similar to access cards that do not provide any means for interaction)</td>
</tr>
<tr>
<td>Credit card</td>
<td>Payment, e.g. payment from credit card account</td>
<td>Users expect interaction on the mobile device to enter a PIN</td>
</tr>
<tr>
<td>Cable</td>
<td>Peer to peer sharing, e.g. sharing digital items between devices.</td>
<td>Users unsure whether interaction should take place on mobile or fixed terminal</td>
</tr>
</tbody>
</table>

Table 2: Four interaction metaphors for PMI and related user expectations (Geven et al. 2007)

Based on a range of user studies exploring these metaphors, the authors (ibid) found that users often had problems forming a mental model of the interaction, as they were unclear about initial interaction points and the sequence of interaction steps. A key issue in particular for the cable metaphor, where digital content is transferred between devices, is that users are unclear about whether to expect feedback on their mobile device or the device they interact with. To address these problems, Geven et al. (2007) recommend to clearly label interaction points and resolve ambiguities through the explicit design of afforances.

FL12: Interactive elements should be clearly labelled and designed to avoid ambiguities

This section discussed interaction models and metaphors for PMI described in the literature. It discussed their specific qualities with respect to users’ expectations and preferences and looked at usability related aspects. The next section first takes a step back to look at the overall user experience of PMI, focusing in particular on touching and pointing as today’s most common interaction models, and then discusses approaches to common problems reported in the literature.

### 2.2.3.4 User experience

Moving on from interaction models and metaphors, this section looks at key aspects of the PMI user experience, including motivations and barriers to engagement, trust and control issues and social protocol when interacting in public spaces.
With regard to users’ motivations, expectations and barriers to PMI, some interesting literature is based on market research exploring the potential of tagging technologies for commercial applications. These studies focus in particular on Quick Response visual markers (QR codes) developed and open-sourced by Denso Wave and Near Field Communication (NFC tags) standardised and promoted by the NFC Forum.

Several reports attest to the spread and public recognition of QR codes (Comscore, 2012; Nellymoser, 2012), however, research shows that the user experience with QR codes is far from satisfying. Investigating why many marketing campaigns involving QR codes deliver poor results, Russel (2011) found that a surprisingly large number of consumers don’t know what QR codes are or how they work. Market research by Aguirre, Johnston and Kohn (2012) shows comparable results for user groups with high digital literacy and smartphone usage, a key target audience for these technologies. Based on user studies involving more than 500 students from 24 US colleges, they found that while QR codes enjoy a high level of awareness among students, only 21% were actually able to scan and activate the code.

A similarly problematic picture emerges for RFID / NFC tags. Deloitte (2013) reports a strong increase of NFC enabled devices, however, a YouGov (2013) study from the same year found that consumers lack awareness and trust in NFC technology, reporting that only 9% of British adults are aware that their phone is NFC enabled and only one fifth of these report ever having used NFC payment functionality of their mobile phone (mobile payments currently being the most popular application for NFC technology). Reasons for this slow uptake might include uncertainty about the interaction and security of NFC tags. Neil et al. (2007) found that while an overwhelming majority of users found NFC technology easy to use once they were introduced to it, only 40% felt that the interaction was clear from the start. Mäkelä et al. (2007) found that users’ conception of storage location and the nature of content were unclear. Most participants assumed that the information was stored in the tag itself, and that the mobile phone would read and store it for later use, indicating weak mental models of tags and tag interaction.

One recurring theme across the literature is users’ concerns about privacy, security and control in PMI. Neil et al. (2007) found in an empirical study that many participants were concerned that tags could be vandalised or purposefully modified to lead the user to bogus services and online scams. Research into exploits of QR codes (Kieseberg et al., 2010) and RFID tags (Verdult and Kooman, 2011) suggests that these are valid concerns that should not be taken lightly. Neil et al. (2007) also report concerns by users that public tag interaction advertises their mobile phone and their intent to bystanders, making them vulnerable to follow-on attacks, and raises curiosity with friends and bystanders, making

\[\text{FL13: SOLs should support both first-time and repeat users}\]
them feel uncomfortable. The latter is echoed in Riekki, Salminen and Alakärppä (2006) who also report that users felt embarrassed to touch tags in public places. As Neil et al. (2007) point out, the nature of the public place seemed an important factor in this context as participants said they would feel more comfortable in high traffic places where people regularly seek information, such as airports or railway stations, than low traffic places where the interaction would attract more attention.

Privacy and security concerns are closely related to trust, which is required in transactions when there is a possibility of consequent loss or harm and the other party can influence whether loss or harm is suffered (Wakeman et al., 2011). An important aspect in this context is control. Riekki, Salminen and Alakärppä (2006) emphasise that users want to have control over the digital environment’s behaviour, and that controllability can have a considerable effect on the acceptance of PMI. As awareness and understanding are key to a feeling of control, they promote clear labelling that indicates which service is associated with a tag. Mäkelä et al. (2007) stress the importance of developing standardised visual clues that help users to recognise tags and their interaction capabilities.

One such effort is described by Riekki, Salminen and Alakärppä (2006), who developed a set of visual symbols for RFID tags that indicate the type of service associated with tag. Usability tests confirmed that users preferred these annotated tags to tags without symbols because they present their meaning in a concrete way (ibid). Continuing this work, Pyykkönen et al. (2012) developed a comprehensive framework for visualising various aspects of tag interaction:

- Attention element: advertising the availability of the service
- Technology element: indicating the technology utilized (e.g. Barcode; NFC)
- Interaction element: indicating the exact point to touch or scan
- Action element: indicating the action triggered by touching the tag
- Context element: defining the context or purpose of the tag
- Chargeable element: indicating whether the service is free or chargeable
- Instruction element: explaining how the interaction is to be performed

(Pyykkönen et al., 2012)

While not all of these aspects are relevant in the context of social object annotation, the framework provides a useful overview of the various aspects that are of interest to users when interacting with tags.

FL14: SOLs should be placed in a way that avoids social embarrassment and unnecessary exposure of users

FL15: The purpose and interaction should be clearly explained to support users forming mental models of SOLs
This section has discussed a wide range of problems in users' overall experience of tags and tag interaction, ranging from misunderstandings and weak mental models to security concerns, social embarrassment and trust and control issues. While some of these problems can be expected to become less relevant as PMI is being used more widely (e.g. weak mental models), others can be expected to remain or become more relevant (e.g. security concerns). While the literature does not provide any conclusive solutions, it helps to better understand these problems and thereby informs approaches to address them.

2.2.3.5 Summary

This section discussed various aspects of PMI, which from a user perspective is one of the most important features of SOLs as it enables them to annotate objects in-situ using their mobile device. The discussion covered object identification, interaction models and user experience. With regard to object identification, the literature provides useful guidelines for identifiers [FL8] and their representation [FL9, FL10], emphasising the need for physical markers to be readable by both humans and machines. Various basic interaction techniques for PMI are described in the literature, including touching, pointing and scanning (Rukzio et al., 2007). Each of these has their own strengths and weaknesses, which make them suitable for different use contexts and user types and indicates that supporting multiple interaction techniques might improve the overall user experience [FL11]. The literature suggests that while users have certain expectations about interaction feedback for some well-known uses of PMI (Geven et al., 2007), there is overall much uncertainty about how PMI works, calling for clear labelling and careful design of interaction points [FL12, FL15] and making sure that they support both first-time and repeat users [FL13]. As several studies point out that PMI in public places can have security implications and lead to social embarrassment, these aspects should be carefully considered when placing SOLs in the environment.

2.2.4 Deployment

Based on observations of how people interact with public displays in the wild, Huang, Koster and Borchers (2008) note that the location and physical orientation of displays often has more influence on user engagement than the actual screen content. Integration with the environment is therefore an important factor to consider in the design and deployment of SOLs.

Calls for ambient displays to blend into the environment, be non-intrusive and easily ignorable (Hazlewood and Coyle, 2009) must be balanced by suitable placement of displays ensuring user awareness and encouraging engagement. Huang, Koster and Borchers (2008) found that displays close to eye-height and next to other eye-catching objects are most effective in attracting and holding users' attention.

FL16: SOLs should be placed at eye-height or close to eye-catching objects to increase awareness.
The height at which SOLs are installed not only impacts on awareness but also on the user interaction. Observing the posture of users while interacting with NFC tags, Hardy et al. (2010a) note that the height of tags directly impacts on the success and ease of interaction.

**FL17:** SOLs should be placed at a suitable height for comfortable interaction

An important aspect in this context is that public and semi-public places are typically governed by Health & Safety regulations and accessibility legislation, which can have a considerable impact on the size, positioning and aesthetics of public displays. For instance, Cheverst, Fitton and Dix (2003) report installing interactive door displays at the relatively low height of approx. 150cm to be accessible to wheelchair users, while Kindberg and O'Hara (2006) report installing signs on lamp posts at a minimum height of 7ft (213cm) to comply with health and safety clauses in local planning laws.

**FL18:** SOLs and their positioning must comply with public law, including accessibility legislation and health and safety regulations, as well as organisational rules and regulations

With regard to the honey-pot effect, which draws in more users when there already is a group of users interacting with a display (Brignull and Rogers, 2003), and the idea that users should be able to interact with a display after a brief period of watching others using it, Kules et al. (2004) suggest that public interactive displays should be placed in a position with a sustained flow of people and sufficient empty space around them for interaction. However, there should not be too much empty space as this can act as a participation threshold.

**FL19:** SOLs should be placed in a position with a sustained flow of people and sufficient empty space around them for interaction

With regard to technical issues, Fitton and Cheverst (2003) report a range of problems encountered when deploying interactive displays in an office environment. The main problems relate to network connectivity and power supply. While the authors (ibid) resorted to wired solutions in their case, this might not be a feasible solution in every target environment and requires careful consideration of connectivity and power requirements.

**FL20:** SOLs should support a range of networking and power options

With regard to monitoring and maintaining displays after deployment, Fitton and Cheverst (2003) describe a Management Agent Web Portal for Hermes displays that provides an overview of deployed displays and enables administrators to check their status, view submitted messages, and view and update users’ personal preferences and temporary
messages. In addition, Fitton (2006) highlights the need to remotely update the software on deployed Hermes displays as manual installation can be tedious and time-consuming.

<table>
<thead>
<tr>
<th>FL21:</th>
<th>The SOL backend should provide functionality to remotely monitor and manage deployed displays</th>
</tr>
</thead>
<tbody>
<tr>
<td>FL22:</td>
<td>SOLs should support remote software updates</td>
</tr>
</tbody>
</table>

While issues relating to the integration of SOLs with the environment only come into play during deployment, they must inform the design from the outset to ensure that they are suitable for installation and user interaction in public places.

### 2.2.5 Summary of ubicomp perspective

The ubicomp perspective can draw on a large body of research into various aspects relevant to the design of SOLs. There is a wide range of taxonomies, design heuristics and design space analyses that help to structure the design space for SOLs and distinguish them from similar display concepts described in the literature. An in-depth review of these sources is provided in Chapter 4 Design space analysis, which develops a design space of SOLs by synthesising design dimensions from existing sources and complementing them with dimensions emerging from the iterative design process.

With regard to awareness and engagement as a key aspect of public interactive systems, the literature provides rich sources modelling attention and providing recommendations on how to encourage engagement. While on the surface there is a marked difference between ambient display research trying to minimise users' cognitive load and public display research trying to attract attention and engage audiences, both research fields offer fine-grained views on how displays can be designed and positioned to address users' peripheral and focused attention and support progression between these stages.

Physical mobile interaction is a key aspect of SOLs, which are driven by user-generated content and require user interaction to browse and add content. The literature provides useful insights in this context relating to object identification, interaction models and metaphors, and describes a wide range of complex user experience problems caused by users' lack of experience with the technology, weak mental models, privacy and security concerns and trust and control issues. The literature also provides suggestions on how to address these issues. The main thrust of these is to provide detailed information on static displays to builds trust, support users in forming mental models of the interaction and thereby foster a feeling of being control.

Integrating SOLs with the environment throws up a wide range of questions ranging from positioning and orientation to compliance with rules and regulations. These aspects have considerable impact on acceptance, user experience and effectiveness of the technology. While primarily relevant at the deployment stage, they do impact on pragmatic aspects.
such as display type and size, connectivity, casings, mounts and power supply, all of which have knock-on effects on technology choices and software design and therefore must be considered early on in the design stage.

The problems and insights described in the literature result in a number of findings:

- [FL1-7] relate to awareness and engagement, emphasising the need to design not only for single users and focused interaction but for both single users and groups of users, and for all stages of engagement from attracting initial attention, to motivating users to learn more about and interact with the display all the way to final disengagement when users move on. They stress that interaction should be intuitive, easy to learn and streamlined, removing potential barriers and avoiding interruptions such as logins and confirmation screens.

- [FL8-10] relate to object identification as one of the key problems in ubiquitous annotation (Hansen, 2006). They cover required qualities of digital identifiers as well as the need to provide alternative encodings for both humans and machines, and making markers quick and reliable to read.

- [FL11-15] relate to the interaction with physical markers, emphasising the need to clearly label interaction points and support different interaction models depending on context and users' preferences. They point out the need to support first-time and repeat users and the requirement to consider privacy, security and social norms when placing SOLs in public environments.

- [FL16-22] focus in particular on integrating SOLs with the environment and managing them after deployment. Requirements in this context relate to engagement, ergonomic use, accessibility and conformance with rules and regulations in the target environment, as well as practical concerns such as connectivity, power supply and support for remote monitoring and maintenance.

Together, these findings provide useful requirements and constraints that can guide the design of SOLs.
2.3 Application perspective

2.3.1 Introduction

While there are many possible applications for ubiquitous annotation, this thesis focuses in particular on social object annotation, where people comment on or rate physical objects or places in their environment. Social object annotation has been enormously successful on the World Wide Web, where visitor comments and ratings are now standard features for most websites. SOLs take inspiration from the numerous social widgets available online that provide meta-data about object annotations (Figure 4).

In an influential blog post entitled "Why some social network services work and others don’t — Or: the case for object-centred sociality", Engeström (2005) proposes that successful social networks are not based on the relationships between people but on people who are connected by a shared object. The shared object, he argues (ibid), is the reason why people relate to each other on a specific social network and it prompts communication between them.

The idea of object-centred sociality has been explored in detail by sociologist Karin Knorr-Cetina (1997), who proposes that in post-social knowledge societies conversations and personal links tend to develop more naturally around social objects, which provoke and maintain interaction between humans. Conceptualising object-centred sociality as the flipside of modern-day individualisation, Knorr-Cetina (ibid) contends that objects and object-centred environments situate and stabilise "selves" and thereby help to define individual identity in a similar way as communities and families used to do.

This section first distinguishes social object annotation from similar applications such as urban annotation and place-based messaging, and then discusses design implications of user-generated content as a key aspect of social object annotation. The section finishes with a brief overview of potential applications in domains other than cultural heritage, which is covered in detail in 2.4 Domain perspective.

2.3.2 Delineating social object annotation

The literature describes several efforts where digital content is attached to physical objects and places and visualised in various ways. These include urban annotation systems such as Urban Tapestries (Lane, 2003), Mscape (Hull, Clayton and Melamed, 2004), Topiary (Li, Hong and Landay, 2004) and InStory (Barrenho et al., 2006), as well as more recent
commercial platforms such as Layar\textsuperscript{10}, Wikitude\textsuperscript{11}, Junaio\textsuperscript{12} and Metaio\textsuperscript{13}, which provide technology infrastructure, authoring tools and mobile augmented reality viewers for digital multimedia content placed in the environment. While these systems generally support ubiquitous annotation, they have limited support for spontaneous in-situ content generation and generally focus on the delivery of a larger experience where people follow a narrative or virtual trail.

Another concept with many similarities to physical social object annotation are place-based messaging systems, which appropriate and digitally enhance the idea of physical Post-it\textsuperscript{14} notes. The literature describes several projects in this field, including GeoNotes (Espinoza et al., 2001), E-graffiti (Burrell and Gay, 2002), Ad Loc (Corbet and Cutting, 2006), HomeNote (Sellen, Harper and Eardley, 2006), Environment Based Messaging (Holleis et al., 2006) and MyState (Hardy et al., 2010b). The following non-exhaustive cross-section of such projects helps to distinguish place-based messaging from social object annotation.

- Stick-e Notes (Brown, 1995) uses GPS coordinates to attach digital notes to objects and places and visualises them via a related application running on a mobile device. Possible applications identified by the author (ibid) include (among many others) placing Stick-e Notes into an environment to support tours, sending paging requests to a specific location and leaving notes for mobile workers.

- Hermes door displays (Cheverst et al., 2003) enable occupants and visitors to leave messages on interactive displays installed outside offices. The project explored the utility of remote messaging on situated displays in an office environment and later spawned the Hermes photo display (Cheverst et al., 2005), which shifted focus towards multi-media messages, mobile interaction and placing displays in specific locations to foster a sense of community.

- Place-its (Sohn et al., 2005), a location-based reminder application, runs on mobile phones and "usefully deviates from the [Post-it] metaphor in that notes can be posted to remote places" (ibid, p.4). The project explored how people might use contextualised reminders in their daily lives. An interesting finding was that the location of notes was often not important in itself but rather a proxy for context that would otherwise be difficult to detect.

- DroPicks (Hosio et al., 2007) explores contextual social content sharing via sentient artefacts, a concept developed by Kawsar, Fujinami and Nakajima (2005) to augment everyday physical objects with digital capabilities. The concept extends previous efforts in place-based messaging by implementing advanced privacy and access controls and, crucially, by providing ambient feedback in the form of sounds or LED lights signalling the availability of content to potential users. Findings of the

project show that users had difficulties understanding and seeing a use for the concept of "digital memo boxes" (Hosio et al., 2007; p.263).

- Beam-Its (Spassova and Butz, 2008) explicitly references Post-its® as its physical pendant and augments this concept by enabling users to attach a variety of text-based and multimedia content to objects and surfaces in the physical environment. Unlike Stick-e notes and Place-its, which display content on a mobile device, and unlike DroPickS, which provide ambient clues to advertise digital content, Beam-Its explores the use of steerable mobile projectors to visualise content in-situ.

- PlaceTagz (Seeburger, 2012) involves placing QR codes in the environment to elicit comments from members of the public and provide "an openly accessible digital layer containing digital augmentations and interactions" (ibid, p.7). The project explores how digital traces mediated through physical artefacts can help people to better connect with urban spaces.

- CloudDrops (Olberding et al., 2015) uses small, "stamp-sized" pervasive displays to show information from the Web in users' everyday environments. Unlike many other systems, which focus primarily on messaging, reminding or notifying users in-situ, the vision behind CloudDrops is to enable users to configure their personal information environment and stay aware of otherwise invisible digital content.

Looking at these projects reveals two key differences between place-based messaging and social object annotation regarding the content and the role of the object or place (Table 3).

<table>
<thead>
<tr>
<th>Social Object Annotation</th>
<th>Place-based Messaging</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Content</strong></td>
<td>Reactions and thoughts about the object they are attached to</td>
</tr>
<tr>
<td><strong>Role of object or place</strong></td>
<td>Subject of discussion</td>
</tr>
</tbody>
</table>

Table 3: Differences between social object annotation and place-based messaging.

One project bridging aspects of place-based messaging and social object annotation is Viewpoint (Taylor et al., 2012), which enables local residents to vote on community issues. The system has features of place-based messaging in that officials can pose a question to be shown on a situated display and residents can cast a binary vote via buttons on the display or via text messages, however, it also has features of social object annotation in that voting happens in a particular community setting that, while not being the subject of the vote itself, emphasises the relevance of the issue under consideration and the authenticity and directness of the public vote.
2.3.3 User-generated content

A key aspect of social object annotation is that annotations are produced, used and consumed by the community, promoting community members from users to "produsers" (Bruns, 2006; 2008) and from consumers to "prosumers" (Toffler, 1980; Ritzer, 2010) who have authorship in, and ownership of, their contributions. Produsage and prosumption brings with them a wide range of problematic aspects relating to attribution and ownership, content moderation, and participation inequality (Nielsen, 2006).

2.3.3.1 Content ownership

Elkin-Koren (2011) points out that copyright is primarily designed to safeguard the rights of a single, sovereign author/owner, whereas social production involves multiple authors whose individual contributions depend on each other. This adds an additional layer of complexity because it "requires us to articulate a matrix of relationships between the individual, the facilitating platform and the communities and crowds involved in social production" (ibid, p.1).

Key aspects in this context are credit and attribution, which have been identified as important motivators in social production and "foundational to the modern economy" (Fisk, 2006). Attribution, in turn, leads to the requirement for users to identify themselves before posting content, for instance by registering and logging in to the system. Attribution, in turn, leads to the requirement for users to identify themselves before posting content, for instance by registering and logging in to the system. In addition to attribution, identification also provides a barrier to posting offensive content and enables host organisations to get in touch with users (Alt et al., 2014).

**FL23:** SOLs should be able to associate content with specific users

Logins, however, interrupt the flow of interaction and should be avoided with a view to streamlining the user experience and promoting engagement (Kules et al., 2004; Brignull and Rogers, 2008) as set out in [FL4]. This view is further supported by Alt et al. (2014), who found in a large-scale online survey that users generally prefer posting content to a public display when no authentication is required.

**FL24:** SOLs should not require users to identify themselves

The conflicting requirements of associating submitted content with a specific user on the one hand and not forcing users to register on the system and identify themselves on the other hand, provides an interesting design tension for SOLs. Taking into consideration that third-party logins via a social network are even less popular than logins via a verified email address (Alt et al., 2014), one possible approach to address this design tensions might be to identify users on a technical rather than personal level, for instance through anonymous device IDs or similar.
Extending the idea of giving users control over content stored on an organisation's platform, Cheverst et al. (2016) explored a distributed model where submitted content is stored in users' own cloud storage and retrieved dynamically for the presentation of collaboratively authored locative media experiences. While this model requires users to have an account with supported cloud storage providers and to grant the system access to their storage, it helps to strengthen their sense of ownership as they can manage submitted media files independently and avoids problems related to handing over content back to contributors when the system is closed down, e.g. when a project or campaign comes to an end.

2.3.3.2 Content quality and moderation

One of the key tensions in open platforms driven by user-generated content lies between giving users an opportunity to share their views in an open, un-censored way while at the same time providing a high-quality experience for users who read comments. Finding ways to encourage high-quality contributions can help towards both of these design goals.

Sukumaran et al. (2011) suggest that commenting behaviour in online communities is influenced by social norms, established through the comments of others, as well as by design aspects of the commenting platform, such as terminology, colouring and layout of the user interface. They found in empirical studies that participants exposed to high-quality content contributed longer comments, spent more time writing them, and presented more relevant thoughts. Interestingly, similar effects were observed for visitors using a more formal and serious design of the user interface. While the former indicates that seeding SOLs with high-quality comments can help to increase the quality of submitted content, the latter suggests that functionality to adapt the terminology and design of the user interface enables host organisations to influence the tone and quality of contributions.

**FL25:** SOLs should give administrators control over the terminology and design of the user interface

In addition to persuasive design measures that encourage high-quality comments, more definite editorial controls might be required to deal with inappropriate and offensive content. Alt et al. (2014) point out that most host organisations have clear expectations and guidelines with regard to the content displayed on their premises, making content moderation a crucial requirement.

**FL26:** SOLs should provide functionality to moderate user-generated content

Greis et al. (2014) identified three basic ways of moderating user-generated content:

- Pre-moderation, where submitted content is held in a queue and screened before being publicly displayed
• Post-moderation, where submitted content is displayed instantly but may be taken down later if found inappropriate
• Moderation based on audience feedback, where submitted content is displayed instantly but may be flagged up by users for moderation

Presuming pre-moderation to be pre-requisite for the acceptance of such systems by host organisations, the authors (ibid) carried out user-studies to establish acceptable time-delays for pre-moderation. Their findings suggest that while most users expect content to be moderated and find delays of up to 10 minutes acceptable, moderation significantly impacts on the quantity of generated posts. As a consequence, they suggest that in order to maximise contributions, organisations should use other forms of moderation where content is displayed immediately. This is further supported by Alt et al. (2014), who found that most participants expect posted messages to appear instantly on the display and that even short delays can lead to users being unsure whether the display works or not, and by Scholl and Tremoulet (2000), who found that delays between action and feedback can destroy the perception of causality when interacting with a system.

**FL27:** SOLs should instantly display submitted content

One way to help with both of these problems, increasing the quality of content and identifying and moderating inappropriate content, is to enlist the help of the community by providing tools that encourage self-regulation. Siersdorfer et al. (2010) found in an analysis of commenting behaviour on popular video sharing site YouTube\(^\text{15}\) that community members rating and flagging each other’s comments can help to promote quality comments and demote or report offensive content.

**FL28:** SOLs should enable users to rate comments
**FL29:** SOLs should enable users to flag comments for moderation

In summary, the literature discusses several ways to increase content quality and moderate comments, ranging from organisational efforts such as seeding systems with high-quality comments to establish a standard for others to follow, to design aspects such as styling displays in a way that encourages quality contributions and providing functionality for users to rate and flag comments. Content moderation in the particular context of museums is discussed in more detail in section 2.4.3 Authority and user-generated content.

### 2.3.3.3 Participation inequality

While content prosumption (Toffler, 1980; Ritzer, 2010) ideally involves users equally in the creation and consumption of content, Nielsen (2006) points out that in most online

\(^{15}\) YouTube. Homepage available [https://youtube.com](https://youtube.com)
communities 90% of users only read content, 9% contribute intermittently and just 1% of users account for the bulk of contributions. Over time, this can lead to the system being dominated by a small group of contributors and content not being representative of the views in the overall community.

To address participation inequality, Nielsen (2006) suggests a range of possible measures:

- Make it easier to contribute.  
  This view is widely supported in the literature and covered in [FL2, FL3, FL4]
- Make participation a side effect of other interaction.  
  In the context of SOLs, this could for example be achieved by recording "reads" when users browse content, which can indicate interest in an object.

  FL30: SOLs should record engagement statistics for objects and comments, including peripheral aspects such as comment reads and ratings

- Edit, don't create.  
  In the context of SOLs, this could be achieved for instance by allowing users to reuse comments when answering to them, or to just rate content instead of commenting.

  FL31: SOLs should support alternative contribution modes such as ratings that do not require actual content creation

- Reward participants.  
  In the context of SOLs this could for example be implemented by recording users' interaction statistics and awarding users accordingly. Crumlish and Malone (2009) suggest a whole range of possible rewards related to a users' reputation, including named or numbered levels, labels or titles and collectible achievements.

  FL32: SOLs should record engagement statistics for individual users

- Promote quality contributors.  
  In the context of SOLs, this could for instance be implemented through a rating system that makes quality contributions more visible. Crumlish and Malone (2009) provide detailed design guidelines for content promotion in a design pattern named "Vote to Promote" (pp. 266ff).

  FL33: SOLs should provide mechanisms to rate or promote contributions

The relevance of these recommendations is further emphasised by the low engagement numbers in similar projects reported in the literature. For instance, Seeburger (2012)
recorded a total of 121 contributions from 150 markers over a 15 months period, equalling 0.05 contributions per marker per month.

2.3.3.4 Summary
Aspects relating to content ownership, moderation and participation inequality are relevant to all applications involving user-generated content. The literature provides useful guidance in this context that can inform the design of SOLs.

2.3.4 Application domains
Social object annotation is a generic concept that can be put to use in a wide range of application domains. While this thesis focuses in particular on applications in museums (discussed in detail in 2.4 Domain perspective), the following sections briefly explore alternative application domains including retail and civic engagement.

2.3.4.1 Retail
The ubiquity of product rating and recommender systems on the WWW and the take-up of physical "Like" buttons and "Check-in" marks to rate local businesses suggest that retail is a promising application domain for social object annotation. Dubach-Spiegler, Hildebrand and Michahelles (2011) point out that retailers' main interest in social networks is that they provide a platform where consumers can discuss their products. This modern form of word-of-mouth promotion has been shown in several studies to be the most influential information when making buying decisions (Jepsen, 2006; Wang et al., 2009; Nielsen, 2012).

Another aspect of user-generated content is that it can be mined for valuable information. In a discussion of economic perspectives of the Internet of Things (IoT), Fleisch (2010) identified user feedback and the value organisations can derive from it as one of the key "IoT value drivers" (p.8). A mobile application based on this idea has since been implemented under the name of my2cents (Karpischek, Michahelles and Fleisch, 2011). The system enables social recommendation and discussion of products in retail environments, based on users scanning the barcodes of products with their mobile device.

2.3.4.2 Civic engagement
Another promising application domain for social object annotation is citizen consultation by local governments on issues of public interest. Schroeter (2012) developed a system that engages citizens in the consultation phase of urban planning projects based on large public displays passers-by can post their opinions to via text message and Twitter. Taylor et al. (2012) developed a public voting device to foster civic engagement in a disadvantaged community where residents can vote on questions posed by local representatives by text

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message or by using buttons on the device itself. Empirical studies suggest that both systems were successful in encouraging engagement and reaching segments of the population difficult to engage by other means. Furthermore, residents seem to appreciate them as attempts by local government to reach out and seek their views.

2.3.4.3 Summary

While this thesis focuses in particular on social object annotation in museums, the above discussion shows that there is a wide range of alternative application domains for SOLs and similar systems.

2.3.5 Summary of application perspective

The application perspective of the research can draw on relevant literature covering various aspects of user generated content in general and social object annotation in particular. The review has briefly discussed the theoretical foundations of social object annotation and delineated it against similar applications such as urban digital annotation and place-based messaging.

With respect to prosumption (Toffler, 1980; Ritzer, 2010) and user-generated content as key aspects of social object annotation, the review has discussed a range of critical aspects including content ownership, content moderation and participation inequality. Each of these aspects informs the design of SOLs:

- [FL23-24] relate to ownership and attribution, emphasising the need to identify users in order to attribute their contributions and give them ownership over them, e.g. with a view to editing content after submission. At the same time, users should not be forced to personally identify themselves as research clearly shows that they prefer systems that do not require them to register and login. This conflict introduces an interesting design challenge for SOLs.

- [FL25-29] relate to content moderation, emphasising the need to moderate content in order to satisfy host organisations’ requirement to have some form of control over content shown on their premises. At the same time, users expect posted content to appear instantly on displays. While by and large they accept the need for moderation and related short delays in content being displayed, the literature clearly states that this negatively impacts on engagement. Again, this conflict poses an interesting design challenge for SOLs.

- [FL30-33] are based on various recommendations in the literature on how to address participation inequality (Nielsen, 2006). They include requirements to record user and interaction statistics as a basis for rewarding users and making participation a side effect of other interaction. They also include requirements to support alternative contribution types such as ratings, which do not require actual content creation, and the need to support content ratings as a means to promote quality contributions.
In addition to informing the design of SOLs, the literature also indicates promising application domains. Besides the cultural heritage domain, which is discussed in detail in 2.4 Domain perspective, the review found similar applications being used in a retail context and for civic engagement, demonstrating the wider utility of social object annotation as an application concept.
2.4 Domain perspective

2.4.1 Introduction

This thesis explores SOLs in first place as a platform for social interpretation of exhibits in museums. As curated spaces with an educational agenda and particular social protocols, museums are complex environments with their own set of requirements and constraints. This section investigates how SOLs fit in with museums' higher-level educational goals, discusses engagement, interaction and technology use in gallery environments and looks at existing curatorial practices to encourage visitor engagement with exhibits. It also reviews previous research efforts in the literature exploring technologies for visitors to comment on museum exhibits and discusses user-generated content in the contexts of authority and public liability.

2.4.2 Museums as places for informal learning

Introducing a report on learning with digital technologies in museums, Hawkey (2004) challenges the popular assumption that schools are for learning and museums for the preservation of the past, suggesting that museums have embraced new technologies and approaches to learning while schools still focus on delivering an outdated curriculum.

The idea of museums as places for informal and lifelong learning has been around for some time and is now ubiquitous in the literature. Screven (1969) understands museums as "responsive learning environments" (p.10); Bradburne (2000) calls museums "support systems for learning" (p.19); Falk and Dierking (2000) call exhibitions "design-rich educational experiences" (p.139) and discuss museums as places for "meaning-making"; vom Lehn (2010), clearly influenced by literature on experiential learning (Kolb, 1984), calls museums "experiential environments" (p.1) and Forrest (2013), keeping with museum terminology, calls exhibitions "interpretive environments" (p.201).

Common to all these views on museums as learning environments is a grounding in social-constructivist (Bruner, 1973; Bandura, 1977; Vygotsky, 1978) and experiential (Kolb, 1984) theories of learning, where visitors encounter learning opportunities and actively construct knowledge by making connections, solving problems, discussing meaning with others and reflecting on their experience. A key requirement for this type of learning is that visitors interact with exhibits and engage in conversations - a "primary mechanism of knowledge construction and distributed meaning-making" (Falk and Dierking, 2000; p.110).

Bradburne (2002) traces the idea of interactivity in museums to science centres, which often need to explain abstract concepts and rely on social-constructivist ideas of learning where visitors re-create phenomena to better understand them. However, he criticises the conventional idea of interactivity as physical manipulation, where visitors pull a lever or push a button, as too simplistic, suggesting that it sometimes leads to shallow and mindless engagement, limits the ways in which visitors can make their own discoveries and overall
does not give an indication of the quality of the visitor experience. He argues instead that interactivity can take many different forms that extend beyond physical manipulation.

Crucially, Bradburne (ibid) conceptualises interactivity not as a property of the exhibit but of the visitor. He introduces the notion of a "user language" as a set of constraints that shapes visitors' engagement with exhibits. As the museums' user language confers properties on both the exhibit and the visitor, it structures their relationship and controls whether interaction takes place and of what nature it is. Bradburne's (ibid) classification of user languages is structured after how they encourage visitors' self-directed discovery and interpretation (Table 4a).

<table>
<thead>
<tr>
<th>User language</th>
<th>Effect on self-directed discovery and interpretation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Authority</td>
<td>Visitor to accept museum as authority</td>
</tr>
<tr>
<td>Observation</td>
<td>Visitor addressed as observer, confers property of being his/her own authority</td>
</tr>
<tr>
<td>Variables</td>
<td>Extension of &quot;observation&quot;, confers ability to see relationships among exhibits</td>
</tr>
<tr>
<td>Problems</td>
<td>Visitor addressed as problem solver, confers ability to analyse problem and act</td>
</tr>
<tr>
<td>Games</td>
<td>Extension of &quot;problems&quot;, makes action a condition of the experience</td>
</tr>
</tbody>
</table>

+ 

| Voice         | Visitor addressed as commentator, confers property of having a public voice |

*Table 4: Bradburne's (2002) five common user languages in museums (a) and Voice as additional user language afforded by SOLs (b).*

Bradburne (ibid) points out that the most commonly used user languages in museums, authority, observation and variables, instruct visitors and determine the role they have to play, while the user languages of problems and games put visitors in the driving seat and only constrain the interaction by providing a solvable challenge and, for games, a set of rules. While SOLs can be used in combination with most of these user languages, in particular observation, variables and problems, e.g. by posing a question for visitors to answer, their unique property of providing a public platform where visitors can express their own views next to exhibits for others to see clearly adds another dimension.

By conferring on museums the property of being interested in visitors as thinking beings (Adams and Stein, 2004), on exhibits the property of being open to interpretation rather than fully described and interpreted, and on visitors the property of having a voice to engage in public debate and balance the museum's authoritative interpretation, SOLs expand the range of user languages available to curators (Table 4b) and support learning through personal interpretation and public debate.

Giving visitors a voice to interpret exhibits from their own point of view is lent additional relevance by Falk and Dierking's (2000) suggestion that visitors do not come as blank slates to the museum but with a wealth of previously acquired knowledge, interests, beliefs and...
experiences. Research has shown that a major barrier to participation in museums is that visitors cannot relate to exhibits based on the information given on object labels (Screven 1992). As SOLs give visitors an opportunity to provide their own interpretation and relate concepts and ideas behind exhibits to their personal experiences, they make the museum experience more relevant and can help visitors to "see themselves within an exhibition" (Falk and Dierking, 2000; p.182).

In order to encourage such behaviour and make the user language of "voice" more instructive, SOLs should offer functionality for museums to display exhibit-specific prompts or questions that help to stimulate and frame contributions. Questions in particular have been linked to a wide range of benefits in the literature, such as encouraging label reading (Screven and Hirschi, 1988), being intrinsically motivating (Screven, 1991), leading to increased involvement and focused attention (Screven, 1991) and generating explanatory conversation among visitors (Hohenstein and Tran, 2007). Useful guidance on how to formulate questions that achieve these benefits are provided by Simon (2008, 2010).

**FL34:** SOLs should support exhibit-specific prompts or questions

Focusing not particularly on learning but on meaningful engagement in museums in general, Simon (2007) identifies five levels of participation:

1. Visitors read and reflect on content
2. Visitors interact with content on their own
3. Visitors interact with content and are aware of others' interaction
4. Visitors interact with content and comment on other's interaction
5. Visitors interact with each other around content

(Simon, 2007)

She suggests that many museums only aim at the first three levels whereas higher levels, which involve visitors commenting on others' interaction (Level 4) or directly interacting with each other around social museum exhibits (Level 5), are more rewarding as they lead to a "deeper connection with the content, greater appreciation for the museum as a social venue, and heightened awareness of other visitors" (ibid, p.1). As a self-contained, easy-to-deploy social commenting platform, SOLs offer museums a simple and affordable way to extend their existing engagement efforts and aim for these higher levels of participation.

**FL35:** SOLs should enable visitors to engage with others' comments, e.g. by replying to or rating comments

Falk and Dierking (2000), who call such efforts "sociocultural mediation" (p.109) and suggest they play a critical role in facilitating visitors' efforts to find meaning, point out, however, that museums are free-choice learning environments and that visitors only choose to engage if they feel in control. Making the interaction easy to understand for first-
time users and giving visitors control over their submitted content are therefore crucial factors for acceptance and engagement with SOLs.

**FL36:** SOLs should be easy to use and understand for first-time users

**FL37:** SOLs should give visitors control over their submitted content

In addition to affording "voice" as a new user language (Bradburne, 2002) and enabling museums to reach [qualitatively] higher levels of participation (Simon, 2007), SOLs meet a wider demand in the literature to incorporate visitors' views into exhibitions. Well-known proponents of this idea include Kelly (2006), who found in a series of studies that "people strongly support the role of museums in providing information ... as long as they provide mechanisms for visitors to make comments" (p.9) and Black (2010), who suggests that "a museum committed to community participation will actively seek user contributions in its galleries... making [it] a public space for opinion and meaning-making" (p.134). Specific measures proposed by Black (ibid) include to incorporate visitors' voices into displays through comment cards or recorded content. Applying these ideas to SOLs has a number of obvious implications, as physically integrating them into gallery displays requires them to work with available networking and power options (FL20), come in form factors suitable for a range of differently sized displays and offer suitable mounting options.

**FL38:** SOLs should come in a range of different sizes

**FL39:** SOLs should support a range of mounting options

In summary, this section discussed museums as places of informal learning. It identified how SOLs can fit into, and extend, museums' efforts to engage visitors and promote learning by fostering conversation and reflection in the gallery space.

### 2.4.3 Interpretive labels

Vom Lehn and Heath (2003) point out that interpretive labels were not always part of the museum experience but only introduced when museums became educational institutions and guided tours gave way to visitors navigating exhibitions on their own. Today, interpretive labels are a standard tool for museums to bridge the knowledge gap between visitors and objects (Loomis, 1983). Their manifold purposes include to provide information about exhibits, orient and instruct visitors, personalise topics and interpret exhibits (Screven, 1992).

SOLs are in many ways the antithesis of interpretive labels - championing the visitor voice rather than the museum voice, affording many-to-many communication rather than one-way top-down communication and showing unverified, potentially biased or trivial comments submitted by visitors rather than authoritative information edited by the
museum. Yet, they also are very similar to interpretive labels in that they are placed next to the exhibit they refer to and should not compete with the exhibit for attention while being conspicuous enough to be noticed by visitors. These similarities make existing research and design guidelines for interpretive labels also relevant for SOLs.

Resonating with HCI research into pervasive displays and public access systems (see 2.2.2), a key theme in the literature on interpretive labels is how to attract and hold visitors' attention. Screven (1992) points out that many visitors do not read labels as the actual exhibits are intrinsically more interesting. This is supported by Bitgood (1996), who remarks that "when given a choice, visitors look at objects rather than read labels" (p.31), adding that labels cannot and should not compete with exhibits for visitors' attention.

Screven (1992) suggests that visitors' decision to engage with a label depends on their perceived value-to-cost ratio, with value depending on visitors' prior experience and goals and cost depending on estimates of time and effort the engagement takes. He offers detailed design recommendations to maximise value and minimise costs, attending in particular to (i) content, in terms of text and message components, (ii) structure, in terms of information design and visual design, (iii) presentation, in terms of format, modality and interaction possibilities and (iv) physical and environmental context.

An even more comprehensive framework of interpretive labels is offered by Bitgood (1996). Based on the three key assumptions that attention is selective, involves focusing power and is of limited capacity, it structures design aspects around (1) stimulus salience and traffic flow with regard to attracting visitors' selective attention, (2) minimising distractions and perceived effort while increasing cognitive-emotional arousal with regard to motivating visitors to focus, and (3) taking into account wider contextual factors to explain museum visitors' decreasing capacity of attention over the course of their visit.

<table>
<thead>
<tr>
<th></th>
<th></th>
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</tr>
</thead>
<tbody>
<tr>
<td>Locate print labels near, or on, the objects they are about</td>
<td>The least amount of effort in label reading occurs when a visitor can look at the exhibit object and read a label at the same time.</td>
<td>FL38, above</td>
</tr>
<tr>
<td>Use clear typography and white space to make labels easy to read</td>
<td>Larger point size and label background increase the attention-getting power of a label.</td>
<td>FL40</td>
</tr>
<tr>
<td>Visitors should require only a little time to find the wanted information</td>
<td>Visitor are more likely to read if information is arranged in a manner that minimized effort</td>
<td>FL41</td>
</tr>
<tr>
<td>Use prompts to challenge and instruct visitors</td>
<td>Labels that ask questions can be effective at provoking label reading; challenge the reader to stimulate problem solving; instruct visitors on what to look for or what to do.</td>
<td>FL34, above</td>
</tr>
</tbody>
</table>

Table 5: Subset of guidelines for interpretive labels and related findings informing the design of SOLs
Screven's (1992) and Bitgood's (1996) guidelines are highly relevant for SOLs as they incorporate a deep understanding of museum visitors and gallery environments. Given that they focus exclusively on museums, are developed primarily for print labels rather than dynamic displays and discuss a great number of very specific aspects, ranging from font-sizes and lighting to visitors' right-turn bias and the attraction of open doors, they are not included in the domain-agnostic design space analysis for SOLs presented in Chapter 4. They can, however, inform the design of SOLs. Table 5 presents a subset of relevant aspects mentioned by both authors and indicates related findings.

| FL40: SOLs should use clear, large fonts and appropriate white space to make them easy to read |
| FL41: SOLs should have a highly optimised information architecture to make information easy to find and read |

Screven (1992) points out that label design typically reflects the values and needs of their "preparers" instead of the values and needs of the people who are supposed to read them. He suggests that museum managers need to become "visitor literate" and focus on label effectiveness by looking at how visitors actually read them. As interpretive labels almost always require adjustments, Screven (1992), Bitgood (1996) and Serrell (1996) all stress the importance of formatively evaluating labels. In addition, Serrell (1996) points out that in-place editing and evaluation of labels enables museum staff to spot problems and try out design variations in the actual gallery environment. As an example she cites the Bisbee Mining and Historical Museum, where staff used a computer and colour printer to quickly edit, print and replace labels informed by visitors' reactions in the gallery space (pp.154ff).

| FL42: SOLs should provide functionality for administrators to monitor and analyse user engagement and interaction. |
| FL43: SOLs should provide functionality to dynamically change screen designs and user prompts even after deployment. |

In summary, this section looked at interpretive labels as a standard communication tool for museums and discussed how research into label design can inform the development of SOLs.

2.4.4 Museums as curated environments

Falk and Dierking's (2000) statement that "people go to museums to see and experience real objects, placed within appropriate environments" (p.139) hints at two key aspects that make the museum experience special. One refers to being in the presence of real, authentic
Latham (2013) uses the term "numinous experiences", appropriated by Gatewood and Cameron (2004) from religious studies to describe the emotional response of visitors to historic battle fields, for the well-known phenomenon where visitors are awestruck, reverential and deeply moved when encountering authentic objects in museums. She contends that regardless of emerging technological trends the physical object is an important aspect of the visitor experience and central to the act of meaning-making.

Complementing this focus on authentic objects is the idea of "museum atmospherics" (Forrest, 2013) as the interplay between visitors and the exhibition environment. While today much of this interplay is characterised by participation and interaction, this was not always the case. In their critique of sociality in museums, Tröndle and Wintzerith (2012) discuss the etymological meaning of "museum" as "art temple" and point out that it has contemplative undertones as opposed to the modern conception as a place where visitors socialise and want to be engaged. They quote 19th century French art writer Quatremère de Quince complaining about "the conversation-addicted masses" drowning out the "fine taste of the connoisseur" just a few years after the opening of the Louvre, and 20th century American art critic Arthur Danto lamenting about the "Disneyfication" of museums.

Research suggests that these misgivings are not unfounded. Tröndle and Wintzerith (2012) found that visitors who converse in exhibitions are less affected by the artworks than visitors who don’t converse and focus on the exhibits. These findings resonate with a recent study by Henkel (2013) who found that visitors who take pictures of artworks remember less details of them than visitors who just look at the artworks. With regard to mobile technologies in particular, vom Lehn and Heath (2003) found that visitors using mobiles as interpretation devices tend to focus on the device screen rather than the original exhibit. As a consequence, "many curators and museum managers are concerned that these new technologies may not only undermine the aesthetic of the gallery but provide resources that distract from, or even displace, the object" (ibid, p.3).

In order to reconcile the communicative needs and technology use of visitors with their contemplative requirements, Tröndle and Wintzerith (2012) suggest that museums must carefully manage an economy of attention, ensuring that visits can be an aesthetic event as well as a social experience. Vom Lehn and Heath (2003) call in this context on developers to "preserve the primacy of the object and aesthetic encounter" (ibid, p.3) when developing interpretive technologies and resources. These views are further supported by more recent research where cultural heritage professionals "stressed the need to use technology in ways that do not distract from the exhibition themes" (Maye et al., 2014, p.601).
In summary, this section discussed the special role of authentic objects in visitors' museum experience and looked at the conflict between social and contemplative conceptions of museums when using interpretive technologies in curated environments.

2.4.5 Social object annotation

Further to Latham's (2013) qualitative research into "numinous experiences", more recent quantitative research has shown that encountering artworks in a museum rather than on a computer screen enhances cognitive and affective processes, with visitors finding exhibits more arousing, positive and interesting (Brieber, Nadal and Leder, 2015). Sharing such immediate experiences with other visitors seems a particularly suitable way to encourage participation and promote learning.

Simon (2010) describes how visitors engage with each other around exhibits using Engeström's (2005) concept of object-centred sociality. However, while Engeström (2005) conceptualises social objects broadly as any physical or metaphysical object around which a discussion can develop, such as photos, jobs or shared interests, Simon (2010) identifies four characteristics that make objects social in a museums context:

- Personal objects we can somehow connect to
- Active objects that focus our attention on them
- Provocative objects that are bound to prompt a reaction
- Relational objects that make us share a common experience

(Simon, 2010)

Taking this idea further, Giannachi and Tolmie (2012) propose that museum objects can become “truly social, shared objects” (p.3) by acquiring their own social profile, followers, persistent URL, user-generated comments and community moderation tools. Considering the uncertainty of any social network's long-term survival and the difficulties of transferring data between social networks, this idea has important implications for system design.

| FL45: Submitted content should be archived and become part of an object's profile |
| FL46: Submitted content should be stored in a future-proof data format |

While designers of Web-based museum experiences have a wide range of well-established tools at their disposal to support object centred sociality and user generated content, curators of physical exhibitions, especially in smaller museums without the necessary budget to develop digital strategies and systems, typically rely on traditional means like visitor books and feedback boards to foster engagement and encourage interpretation in the gallery space.
A recent report into technology use in English museums (MTM, 2013) shows that digital technologies are seen as essential to marketing and audience development, however, in-gallery technologies supporting visitors’ annotation and interpretation of exhibits are rare.

An early effort exploring this space is based on two systems, VideoTraces and ArtTraces, which enabled visitors to interact with each other around their ideas, interpretations and questions about exhibits (Stevens and Toro-Martell, 2003). Both systems are kiosk installations in the gallery space. They enable museum visitors to annotate digital images or videos with recorded speech or gestures and share them with other visitors. While VideoTraces enabled visitors to record the annotated base image or video on the spot, ArtTraces provided base images and videos of installations created by the museum. The authors point out (ibid) that these traces can work as boundary objects (Star and Griesemer, 1989) that can be used inside and outside the museum to different spheres such as museums and schools and thereby broaden an exhibition’s impact.

Van Loon et al. (2006) present research around ARCHIE, a handheld guide with in-built functionality to stimulate interaction with other visitors and the museum. Citing previous research by Vom Lehn and Heath (2005), which shows that the use of handheld devices in galleries can lead to isolated experiences and visitors paying less attention to the actual exhibits, Van Loon et al. (2006) integrated communication, personalisation and localisation functionality into a collaborative game to be played on handheld devices in the gallery space. The game is anchored around exhibits, assigns players different roles and enables players to communicate via voice or other media, thereby promoting social interaction to support visitors’ intellectual, social, and cultural development.

Seirafi and Seirafi (2011) report on FluxGuide, a commercial system for museums to present digital information on mobile devices and enable visitors to add their own commentary about exhibits. The system deeply integrates with museums’ IT infrastructure to access digital materials about exhibits and uses social media as a commenting platform. A key aspect discussed by the authors is that the system extends the traditional one-way communication from museum to visitor to a model where information flows in both directions and between users, thereby enabling new forms of interpretation and learning.

Hsu and Liao (2011) describe a prototype mobile application at the Exploratorium science gallery in San Francisco integrating self-guided exploration of an exhibition with social object annotation. The system uses RFID technology to provide visitors with digital information about exhibits and to anchor user-generated comments, and visitors can share posted comments on their preferred social network. In order to protect the museum and its visitors from inappropriate user-generated content, comments are pre-moderated, i.e. they are accessible to the public only after they have been approved by the museum.
Girardeau et al. (2015) describe interpretive technology at the Fine Arts Museums of San Francisco (FAMSF) where visitors use their mobile phone to listen to audio interpretations of both curators ("museum voices") and other visitors ("community voices"), as well as record their own audio comments in response to prompts. The system is conceptualised in first place as a soundscape for visitors to explore at their own pace. Depending on personal preferences, they can choose to listen to museum or community voices or a mixture between the two. Comments recorded by visitors go live immediately and are post-moderated later on to ensure they comply with the museum's acceptable use policy. While the authors report that most of the visitor comments are useful and insightful, they also indicate that, in response to early user feedback, the system is being developed further to enable visitors to vote on the quality of comments [see FL28] in order to prioritise and promote content they like.

**FL48:** SOLs should prioritise comments according to their community rating

Perhaps the most relevant research in this context was carried in the QRator (Gray et al., 2012) and Social Interpretation (SI) (Bagnal et al., 2013) projects, both of which explored social object annotation in museums and used technologies developed in their common precursor project Tales of Things (Barthel et al., 2010). The projects involved kiosks in the exhibition space, which were equipped with touch screens for display and user input, and printed QR codes on the object labels for each exhibit, which were scanned by visitors using their mobile device. Kiosks were used as a prominent way for curators to pose topical questions relating to the exhibition and collect visitors' responses, while QR codes were used as a more peripheral mechanism to collect visitors' comments about specific exhibits. Both projects used a post-moderation approach where user-generated content showed up instantly on the system but could be taken down later if deemed inappropriate by the museum.

The SI project found that only about one third of visitors engaged with the kiosks, the vast majority of whom read only content. Only 2% of visitors to the IWM London and 8% of visitors to the IWM North actually made a comment of some kind (Bagnal et al., 2013). Engagement rates for QR codes were even lower with 0.1% at IWM London and 1% at IWM North (ibid). While in visitor interviews most respondents claimed to have noticed the QR codes, only two out of ten staff report ever having observed visitors scanning a QR code (ibid). This is confirmed in a separate report about the SI project by Giannachi and Tolmie (2012), which found that despite frequent iterations in the way QR codes were presented, they were ignored by a vast majority of visitors. Based on their experiences, Giannachi and Tolmie (2012) recommend to streamline the experience of engaging with QR codes.

This echoes research findings relating to public engagement with interactive displays (Brignull and Rogers, 2008) and incidental use systems (Kules et al., 2004) and further

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18 Imperial War Museum (IWM). Homepage http://www.iwm.org.uk/
supports [FL4] calling for a streamlined user experience. With regard to concrete measures, the authors recommend that visitors should not be required to install an application or login before they can use the codes and that the museum should provide a reliable WiFi connection across the gallery space.

| FL49: | SOLs should not require users to install a custom application |
| FL50: | SOLs should not require users to login to read or contribute content |
| FL51: | SOLs should be tolerant of unreliable network connections |

In addition to technical measures, Giannachi and Tolmie (2012) suggest that QR codes need suitable framing that gives visitors a clear reason why to scan the code and why to share their thoughts. They point out that this requires a comprehensive organisational effort to promote an active and social visitor experience. Sayre (2015) develops this idea further with particular emphasis on supporting BYOD (Bring Your Own Device) programmes where visitors use their own mobile phones in museums. He identifies eight variables determining the success of BYOD in museums and discusses how each of them can be addressed to frame and support visitors’ mobile engagement.

| FL52: | SOLs should be framed in a comprehensive organisational effort to promote mobile technologies and a social visitor experience |

A theoretical grounding for the idea that social object annotation in museums, or BYOD programming in general, needs appropriate framing is provided by DiSalvo, Maki and Martin (2007). They introduce the concept of a “constructed public”, based on John Dewey’s (1927) idea that a public does not exist a priori but is brought together around a meaningful social condition. This move away from “the public” as a general population towards “a public” as a selective subset of that population primed for engagement in a specific context has important implications for the design and evaluation of interactive public systems. In a design context, it presumes awareness of the system’s existence and interest in, or even agreement with, its purpose and aims, shifting part of the responsibility for these aspects from system design to the wider user experience design. In an evaluation context, it takes into account whether and how a public was created around the system as an important factor in its adoption, going beyond classic aspects such as perceived usefulness, perceived ease of use (Davis, 1989) and perceived social norms (Venkatesh and Davis, 2000) as the main factors for technology acceptance.

In summary, the literature describes several efforts involving technology to support users communicating with each other and with the museum. It offers valuable guidance on how to implement, frame and support social object annotation in museums.
2.4.6 Authority and user-generated content

A key aspect of user-generated content displayed in museums is quality. From a museum's perspective, inappropriate or wrong content not only impacts on the visitor experience but also undermine the organisation's authority, which is a distinguishing quality specifically for heritage organisations (Oomen and Arroyo, 2011).

The literature indicates a conflict in this respect between visitors' user experience and preferences and museums' reluctance to yield control over the content displayed in their gallery space. On the one hand, research by Kelly (2006) indicates that museum visitors like to comment on complex and controversial topics, and research by Gray et al. (2012) shows that instead of their comment being held in a moderation queue, visitors expect it to be displayed instantly after input. On the other hand, there is a deep-seated fear among museum professionals that visitors leave inappropriate comments that are displayed unchecked in the gallery and might reflect negatively on the museum (Gray et al., 2012). Commenting systems in museums must therefore implement moderation mechanisms [see FL26] that do not compromise the user experience while enabling museum professionals to hide or delete inappropriate or wrong content.

One approach to addressing this problem is discussed by Stevens and Toro-Martell (2003). Acknowledging that wrong or misleading comments can negatively impact on museums with respect to their role of providing authoritative scholarly knowledge, they suggest that such misrepresentations should be addressed by both other visitors who might post opposing views and the museum who can directly respond to such content and thereby demonstrate their expertise in a hands-on manner rather than through distanced authority.

With respect to inappropriate (rather than wrong or misleading) user-generated content, a similar idea is supported by Russo (2008) and Gray et al. (2012). Both of these publications cite Fichter's (2006) concept of radical trust, where abuse and vandalisms are accepted as being part of society but (radical) trust placed in the community relies on its members to deal with these issues and safeguard continued operation.

A moderation mechanism implementing these ideas is described in Gray et al. (2012) for the QRator project and Bagnal et al. (2013) for the SI project. It combines traditional post-moderation, where comments show up instantly and can later be taken down by museum professionals, with user-moderation, where visitors can flag up comments for museum professionals to look at. The advantage of this system is that it allows content to be displayed instantly while providing a certain level of control and being operable with limited resources. Based on Gray et al.'s (2012) observation that spamming and inappropriate commenting did not happen to a significant extent in the QRator project, a lightweight approach involving visitors to flag comments for moderation [see FL29] seems acceptable.
In summary, this section looked at conflicting needs of visitors and museums with respect to the moderation of user-generated content. It established the need for content moderation in principle and discussed a lightweight approach satisfying the requirements of both visitors and museums.

2.4.7 Summary of domain perspective

The domain perspective of the research can draw on a large body of literature discussing informal learning, engagement and interaction in museums. The review clearly identifies how SOLs can help museums towards their higher-level educational goals by extending their "user language" (Bradburne, 2002) to give visitors a public voice in the interpretation of exhibits and by enabling qualitatively higher levels of participation (Simon, 2007) that emphasise social aspects of the museum experience.

With regard to introducing interpretive technologies into museums, the literature emphasises the importance of authentic objects and curated environments for the visitor experience and cautions against technology challenging the "primacy of the object" (vom Lehn and Heath, 2003) and disturbing aesthetic and contemplative experiences in museums. Research into interpretive labels offers important insights in this context and informs a number of design considerations, ranging from information design to evaluation support.

The literature describes several recent efforts to support in-gallery object annotation in museums. While these efforts usually involve kiosks or static markers with information presented on the mobile device, rather than dynamic displays deployed next to exhibits as is the case with SOLs, they still provide valuable insights informing both the design of SOLs and their integration with the museum environment.

Concerning the disruptive nature of user-generated content with regard to the museum’s authority and its role of providing verified scholarly knowledge, the literature suggests that open approaches where misleading comments are corrected in curated responses are an effective way for museums to practice authority. With regard to inappropriate or offensive content, the literature suggests that involving the community in comment moderation strikes a good balance between response time and required resources.

Overall, the literature provides valuable insights that inform a number of domain-specific as well as more general requirements for SOLs relating to:

- Visitor engagement and learning [FL34, 35, 36, 37, 47, 49, 50]
- Information architecture and presentation [FL40, 41]
- Content rating and moderation [FL48, FL53]
- Integration with the gallery environment [FL38, 39, 44, 51, 52]
- Administration, configuration and evaluation [FL42, 43]
- Conservation and access to content [FL45, 46]
Together, these requirements are particularly relevant for SOLs in a museum context as they are informed by research in the cultural heritage domain and draw on the experience of other projects exploring interpretive technologies in museums.
2.5 Methodology perspective

The research employs a user-centred, iterative design approach in which evaluation is an integral part of the development process at all stages. While there are well established approaches and methods to support the earlier stages of the user-centred design process, such as personas (Courage and Baxter, 2005), scenarios and paper prototypes (Saffer, 2010), there are currently no commonly accepted guidelines as to how public display applications should be evaluated (Alt et al., 2012). This section focuses in particular on approaches and methods supporting the evaluation of advanced prototypes of SOLs.

2.5.1 Approaches and methods

There is a broad consensus in the literature about the need to evaluate ambient information systems in the wild. Abowd and Mynatt (2000) argue that important dimensions in ubicomp such as device, space, people and time make it impossible to use traditional lab-based evaluation methods and that in-depth evaluation therefore requires "real use of a system, and this, in turn, requires a deployment into an authentic setting" (ibid, p.48). Hazlewood and Coyle (2009) point out that because ambient displays are designed to be subtle and unobtrusive and are often used indirectly, controlled laboratory studies do not give enough insight to help predict how these technologies are experienced in an actual context of use. This is supported by Ju and Sirkin (2010), who stress the need for research into awareness and acceptance to be carried out in authentic settings as users behave differently in public spaces than in a lab, and by Abowd (2012), who states that in real-world settings users put more emphasis on improvisation and less on following a-priori plans. Alt et al. (2012) add that even if a realistic environment could be recreated it would be impossible to simulate the dynamic flow of people due to a lack of suitable models.

The challenge is therefore to design suitable experiments that help to find out how people interact with such systems in public settings, where they may provoke behaviours and responses that are difficult to predict. Hazlewood and Coyle (2009) call for researchers to develop methods that can:

- determine whether users perceive information on ambient displays as intended
- describe how their behaviour is influenced by the information provided
- measure the level of distraction produced by an ambient display
- characterise the effects of an ambient display on the overall user experience

(Hazlewood and Coyle, 2009)

While these aspects focus primarily on information delivery rather than interaction and content creation, they are still highly relevant as they can inform how SOLs should present information and integrate with the environment and the mobile device. It would be particularly helpful in this context if presentation parameters could be changed dynamically on SOLs without requiring hardware or software changes. Combined with analytics data
about users' interaction and suitable tools to analyse that data in real-time (see FL42), it would enable researchers to investigate these aspects in realistic environments. These

| FL54: SOLs should collect detailed analytics data about users' interaction and make it available in real-time |
| FL55: SOLs should be able to dynamically change information presentation parameters to support their evaluation in the field |

This idea is further supported in a domain context by Maye et al. (2014), who report that many cultural heritage professionals call for technologies to not only offer engagement opportunities for visitors but also afford curatorial and management activities, "such as the ability to tweak, maintain and modify the design" (p.603), and more generally for ambient technologies by Hazlewood, Stolterman and Conolly (2011), who suggest that integrating evaluation aspects into the design of ambient displays can help to unobtrusively detect how users perceive and react to them, thus creating the necessary conditions for long-term evaluation studies that investigate how people make use of ambient displays once the novelty effect wears off. While the latter's proposed use of gaze detection, sentiment analysis and location tracking (ibid) raises profound ethical implications when used in public settings and without informed consent by an unsuspecting public (Luger and Rodden, 2013), anonymous analytics data about explicit interactions, as commonly collected on Web pages, is less controversial and still holds useful information.

Other commonly used methods to evaluate public displays identified in Alt et al. (2012) include (i) interviews, often semi-structured and conducted in-situ to assess users' views, (ii) questionnaires, either standardised or customised, for quantitative evaluation aspects, (iii) focus groups to discuss early designs and prototypes and (iv) observations to assess audience behaviour, effectiveness, social impact.

Korn and Bødker (2012) point out that traditional field trials involving fully functional prototypes in naturalistic settings are "problematic as part of an iterative design process as they frequently result in looking back rather than ahead" (p. 2). To address this problem, they suggest an openly interactive approach that involves users early on in the design process and call for greater innovation in methods that break away from the assumption that trials should be as natural as possible. To support such innovation, they propose a taxonomy of ubicomp evaluation methods with five dimensions, each spanning from traditional lab studies on one end to in-the-wild studies on the other end (Table 6).

In order to complement costly empirical evaluation with more lightweight methods that provide quick and inexpensive feedback, Mankoff et al. (2003) adapted heuristic evaluation (Nielsen and Molich, 1990) for ambient displays by developing a suitable set of heuristics. These take into account that ambient displays are not actually "used" in the way that office software is (for which heuristic evaluation was originally developed) but rather "perceived"
2.5.2 Working with museum staff

Regarding the design, development and evaluation of interactive technologies in museums, recent research discusses what designers and technologists can learn from museum professionals (Maye et al., 2014), looks at co-design processes and their benefits and limitations (McDermott, Maye and Avram, 2014; Ciolfi et al., 2016) and explores the relationship between research teams and museum staff (Petrelli et al., 2016).

An interesting finding in Maye et al. (2014) is that cultural heritage professionals typically design interactive exhibitions around core concepts such as stories, themes or museum objects, and only later look at how technologies can support that concept. This is in stark contrast with design research, which typically revolves around a technology artefact, and a reminder that for museum professionals SOLs are just one of many possible technologies to employ rather than a platform that forms part of design considerations from the outset.

Looking at cooperative design processes involving technologists and museum staff, Ciolfi et al. (2016) distinguish between open and prototype-led co-design, with the former placing more emphasis on explorative techniques such as brainstorming and rapid prototyping and the latter focusing on adapting, modifying and contextualising an existing prototype for a specific museum environment. With regard to prototype-led co-design in particular, they point out that defined concepts and physical prototypes favour convergent thinking processes and can make it more difficult for participants to envisage alternative implementations. Similar points are made by McDermott, Maye and Avram (2014), who warn that physical artefacts can be both stimulating and limiting as they can help to identify requirements and encourage museum staff to think of technology in new ways but also can put too much focus on the technology itself and thereby obscure the real needs of cultural heritage professionals.

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Table 6: Taxonomy for ubicomp evaluation methods. Adapted from Korn and Bødker (2012).

<table>
<thead>
<tr>
<th>Dimension</th>
<th>Lab Setting</th>
<th>↔</th>
<th>In-the-Wild</th>
</tr>
</thead>
<tbody>
<tr>
<td>Use situation</td>
<td>artificial</td>
<td>↔</td>
<td>realistic</td>
</tr>
<tr>
<td>Involvement of investigator</td>
<td>high</td>
<td>↔</td>
<td>low</td>
</tr>
<tr>
<td>Participants</td>
<td>recruited</td>
<td>↔</td>
<td>attracted</td>
</tr>
<tr>
<td>Time</td>
<td>compressed</td>
<td>↔</td>
<td>real-time</td>
</tr>
<tr>
<td>Sophistication of prototype</td>
<td>incomplete mock-up</td>
<td>↔</td>
<td>complete functional</td>
</tr>
</tbody>
</table>

by users who obtain information passively (Mankoff et al., 2003). As there is only a partial overlap between ambient displays and SOLs, Mankoff et al.’s (2003) heuristics might not be suitable to evaluate SOLs. However, as one of the research aims is to develop design recommendations for SOLs, heuristic evaluation might become a useful instrument in the future. Despite being limited to evaluating the potential success of a design, they can add rigour through methodological triangulation (Denzin and Lincoln, 2005) with empirical methods assessing actual use and acceptance.
More hands-on advice on cooperating with museum professionals is offered in Petrelli et al. (2016), who discuss a number of aspects they found to contribute to a successful outcome of multidisciplinary and iterative design processes involving curators, designers and technologists:

- Involving people who feel at ease with discussing ideas openly and without judgement, not discarding unconventional ideas too quickly and not being defensive when ideas are criticised, discarded or changed.
- Acknowledging that iterative design may be common with designers but not with museums professionals, who typically take a more traditional approach to exhibition design based on decision making rather than experimentation.
- Acknowledging the messiness of the design process and accepting the importance of failing often and early on to eliminate weak ideas and reduce the effort spent on unfeasible or impractical solutions.
- Committing team members to the co-design process in the long run and fostering a sense of ownership among participants that is beneficial at both development and deployment stages.
- Maintaining good communication when team members break out to develop their own component/contribution, to show progression, share artefacts and uphold a sense of shared ownership.
- Testing assemblies of technologies early on, preferably with real content and in place, as this can lead to relevant insights giving the process fresh impetus.

(Petrelli et al., 2016)

While these recommendations are based on the authors’ experiences in large international projects involving multidisciplinary teams, their emphasis on good communication, mutual understanding, shared ownership and iterative design and evaluation make them also relevant for the present research project.

### 2.5.3 Validity and transferability

Based on an extensive review of research papers concerned with public displays or digital signage, Alt et al. (2012) point out that "most studies can be criticized as not exercising sufficient control over confounding variables (internal validity), not generalizing to other settings and situations (external validity), or not testing a realistic situation (ecological validity)" (ibid, p.5). As these different aspects of validity are difficult to satisfy all at once, they recommend that studies should make clear which aspect of validity they focus on and how other aspects of validity are dealt with. This advice is particularly helpful in the context of design research, which uses a range of approaches and methods to inform the design and evaluation of artefacts together with users. Discussing aspects of validity for each study will help to identify limitations in the research and make it more transparent.
With regard to transferability, Scholtz and Consolvo (2004) note that the lack of a widely accepted framework for ubicomp evaluation makes it difficult to compare research results. To address this issue, they developed a set of *Ubiquitous Computing Evaluation Areas*, together with metrics and conceptual measures for researchers to adapt to their specific situation and needs. However, while the framework provides a useful overview of ubicomp evaluation aspects, it may be too rigid and high-level for the present research, which is developmental in character and necessarily focuses on specific aspects in order to make a contribution rather than evaluating SOLs against a fixed set of general ubicomp aspects. However, the framework can provide a standardised vocabulary that might help others to identify aspects in the research which are of interest to their own efforts and therefore help to transfer and validate findings.

### 2.5.4 Summary of methodology perspective

Given that the user-centred design process is generally well understood in the field of HCI, the methodology perspective of the review focused in particular on the more problematic aspect of evaluating ubicomp technologies, which poses particular challenges.

One of these challenges is that ubicomp technologies are designed for situated use and empirical evaluations should take place in the intended use context in order to yield useful results. While there is general agreement in the literature about the value of evaluating ubicomp technologies in the wild, it is equally acknowledged that field studies are very costly and therefore need to be balanced with cheaper and more lightweight methods. Another challenge is that it is difficult to measure users' awareness of, and attention to, ambient technologies without actively drawing their attention to them. The literature suggests to integrate technologies for automated data collection into ambient displays that can detect the gaze and movement of passers-by, however, ethical considerations make this approach highly problematic.

With regard to inspection and hybrid methods, the review discussed Mankoff et al.'s (2003) adaptation of heuristic evaluation for ambient displays as an important effort to complement costly field studies with a discount and lightweight evaluation method for ubicomp technologies.

With regard to the validity and transferability of evaluation results, the review discussed Scholtz and Consolvo's (2004) framework of ubiquitous computing evaluation areas (UEAs) and their usefulness in providing a standard vocabulary when sharing research findings.

In addition to informing the methodology of this research, the methodology perspective in this review also identified the requirements for SOLs to collect analytics data about users' interaction and provide functionality to dynamically change design parameters to support their evaluation in the field. While these are not required for the operation and use of SOLs, they are important in the context of iterative research and development as they support the ongoing, data-driven refinement of designs.
2.6 Conclusions

This chapter has reviewed relevant literature from ubicomp-, application-, domain- and methodology perspectives in order to contextualise the research, identify requirements for SOLs and inform the research methodology.

From a ubicomp perspective, it has identified display taxonomies and heuristics that can inform the design space analysis in Chapter 4 and has discussed aspects around awareness, engagement, physical mobile interaction and integration with the environment. In the process, it has identified a range of findings informing the SOL design on each of these aspects (FL1-FL22, Appendix A1), which are discussed in the ubicomp summary (see 2.2.5).

From an application perspective, the review has distinguished social object annotation from similar concepts such as urban annotation and place-based messaging, and discussed aspects around the social production and consumption of content, including ownership, moderation and participation inequality. Specific findings for each of these aspects (FL23-FL33, Appendix A1) are discussed in the application summary (see 2.3.5).

From a domain perspective, it has identified how SOLs can support museums’ higher-level educational goals, discussed potential conflicts with aesthetic and contemplative experiences in museums and reviewed previous experiences with in-gallery social object annotation. Specific findings for each of these aspects (FL34-FL53, Appendix A1) are discussed in the domain summary (see 2.4.7).

Finally, from a methodology perspective, the review has discussed benefits and challenges of evaluating ubicomp applications in authentic settings, advantages and limitations of inspection methods and approaches to increasing rigor in evaluation studies and making them easier to compare. Findings are discussed in the methodology summary (see 2.5.4) and inform both the design of SOLs (FL54-FL55, Appendix A1) and the research methodology in Chapter 3.
3 Methodology

3.1 Introduction

The research defines, structures and systematically explores a design space for SOLs with a view to developing empirically validated design recommendations that can inform future research and development. As design problems are open ended, cannot be fully specified (Lawson, 1980) and have a multitude of parameters that depend on each other and on the context of use (Saffer, 2010), a positivist approach involving parameterised experiments in a controlled environment is not appropriate. Neither is an interpretive approach suitable, because the research is developmental in character and involves the introduction of design artefacts, as both the vehicle and object of the research, into the researched situation.

Design Research (March and Smith, 1995; Edelson, 2002; Vaishnavi and Kuechler, 2009), variants of which are also known as design experiments (Brown, 1992; Collins, 1992; Cobb et al., 2003), development research (Akker, 1999), design-based research (Design Based Research Collective, 2003), design-science research (Hevner et al., 2004) and research through design (Zimmerman, Stolterman and Forlizzi, 2010), is a suitable methodological framework for the proposed research. Unlike positivist approaches, which aim to prove or disprove a hypothesis, or interpretive approaches, which try to interpret a phenomenon through observation and meaning-making, the primary goal of design research is to bring about improvement in the phenomenon of interest (Purao, 2002) by refining both theory and practice (Collins, Joseph and Bielaczyc, 2004).

Design Research is widely adopted in the fields of Information Systems (IS) and Technology Enhanced Learning (TEL) for the development of technological products, applications and services. Vaishnavi and Kuechler (2009) provide a comprehensive overview of Design Research in IS, while an analysis and critique of Design Research specifically from an HCI perspective is offered by Zimmerman, Stolterman and Forlizzi (2010).

The design research approach adopted in this thesis draws in particular on March and Smith (1995) and Hevner et al. (2004), who emphasise the critical role of evaluation in the design process as a means to better understand the problem at hand and improve designs in a "build-and-evaluate loop" (Hevner et al., 2004; p.78) involving users and other stakeholders.

Design Research mixes qualitative and quantitative methods. It typically employs qualitative methods in the earlier stages of research to gain a detailed understanding of stakeholders’ mental models, needs and preferences, and complements these with quantitative methods in the later stages to measure the effectiveness and efficiency of specific implementations when the focus shifts to refining and optimising designs.

A key aspect of design research that strongly resonates with the need to evaluate ubicomp applications in the wild (Abowd and Mynatt, 2000; Hazlewood and Coyle, 2009; Ju and Sirkin, 2010) is that it aims to evaluate advanced prototypes in realistic environments to get
a better understanding of “the problem space in which the phenomena of interest reside” (Hevner et al., 2004; p.79) and avoid distortions of laboratory settings (Collins, Joseph and Bielaczyc, 2004), helping to increase the ecological validity of the research (Alt et al., 2012).

3.2 Overview of research process

The research is broadly structured into three phases, including reconnaissance, iterative design and evaluation, and conceptualisation and validation (Figure 5):

![Figure 5: Overview of research process](image-url)
Chapter 3 Methodology

Phase 1: Reconnaissance

The aim of the reconnaissance phase is to get a better understanding of the design space for SOLs, of potential users and of the context in which they are deployed and used in. In addition, preparatory work is carried out to support the iterative design and evaluation in the next phase.

A key objective is to define and structure the design space for SOLs, which provides a basis for its systematic exploration. This involves identifying similar display concepts described in the literature, distinguishing SOLs from these display concepts and analysing and synthesising relevant taxonomies and design heuristics. The resulting shared design aspects are later complemented with aspects emerging from the iterative design and evaluation.

Another key objective is to better understand potential users of SOLs in a museum context. This involves reviewing existing audience research, surveying visitors’ preferences, expectations and conceptual models of commenting in museums and developing personas (Courage and Baxter, 2005) and scenarios (Rosson and Carroll, 2003; Nathan, Klasnja and Friedman, 2007) to model realistic uses of SOLs in the target environment.

Preparatory work in this phase include the development of early design studies and mock-ups that can serve as a starting point for discussions with users and museum professionals, and preliminary technological explorations to identify viable architectures and constraints.

Phase 2: Iterative design and evaluation

The aim of this phase is to systematically explore the design space for SOLs, based on the preliminary structure developed in the reconnaissance phase, and in the process to further map out the structure and generate knowledge that can inform design recommendations.

Each iteration identifies requirements, makes design choices to meet those requirements, develops design artefacts and prototypes implementing the design choices and evaluates them together with users. As successive iterations inform each other, the overall design of SOLs is incrementally refined and artefacts develop from partial solutions and low-fidelity prototypes (Appendix B1-3) to high-fidelity prototypes suitable for deployment in realistic environments (Appendix B4-7).

Specific research activities in this phase include user-testing and co-design sessions to formatively evaluate design artefacts, expert interviews with museum professionals to explore organisations’ requirements and get formative feedback on prototypes, and field trials in museums to empirically evaluate advanced prototypes with high ecological validity.

Other work in this phase includes the selection of suitable prototyping hardware platforms, software development to create the SOL application, backend services and mobile application, and the design of casings for mounting SOLs in the gallery space.
Phase 3: Conceptualisation and validation

The aim of this phase is to review and synthesise findings from the research activities, write up the research and prepare for a defence by summarising its findings, reflecting on its contribution and setting out future work.

A key objective is to revisit the design space analysis from the reconnaissance phase and complement its design aspects with salient aspects emerging from the iterative design and evaluation, resulting in a consolidated design space structure for SOLs.

Another key objective is to formulate design recommendations for each aspect in the developed design space structure, by drawing on findings from all research activities and providing supporting evidence and implementation examples from the developed prototypes and empirical evaluations.

Outcomes

Table 7 maps the potential outcomes of Design Research, synthesised from Purao (2002) and Vaishnavi and Kuechler (2009), to research outcomes presented in this thesis.

<table>
<thead>
<tr>
<th>Outcomes of Design Research (Purao, 2002; Vaishnavi and Kuechler, 2009)</th>
<th>Relevant research outcomes discussed in this thesis</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constructs: the conceptual vocabulary of a domain</td>
<td>Definition and delineation of the design space for SOLs</td>
<td>Chapter 4.2</td>
</tr>
<tr>
<td>Models: a set of propositions expressing relationships between constructs</td>
<td>Ten high-level design aspects; Tensions between design aspects</td>
<td>Chapters 4.7; 4.8</td>
</tr>
<tr>
<td>Methods: a set of steps used to perform a task (e.g. evaluation methods and tools)</td>
<td>Attention potential of placements; Data analytics and visualisation tool</td>
<td>Chapters 8.5.2.1; 8.5.5.2; 8.5.3.3</td>
</tr>
<tr>
<td>Instantiations: the operationalisation of constructs, models and methods.</td>
<td>Implementation examples based on SOL prototypes and deployments</td>
<td>Chapter 9; Appendix B</td>
</tr>
<tr>
<td>Theories: goal-oriented and prescriptive metaphorical knowledge derived from the design process (e.g. design principles)</td>
<td>Design recommendations based on findings from the research</td>
<td>Chapter 9</td>
</tr>
</tbody>
</table>

Table 7: Mapping potential outcomes of Design Research to outcomes of the present research

3.3 Approaches and methods

Based on an extensive literature review, Alt et al. (2012) identified five commonly used evaluation approaches to inform the design and evaluation of public displays, including ethnography, asking users, lab studies, field studies and deployment-based research. The research underpinning this thesis uses three of these approaches (asking users, lab studies, field studies) and complements them with iterative prototyping as a development approach.
commonly used in software engineering (Larman, C., 2003) and with persona development (Courage and Baxter, 2005) and scenario-based design (Rosson and Carroll, 2003), both of which are established user-centred modelling approaches grounded in design practice. Table 8 provides an overview of approaches and methods used in the research, together with references to sections in this thesis where they are described in more detail.

<table>
<thead>
<tr>
<th>Approach</th>
<th>Method</th>
<th>Data analysis</th>
<th>Ref.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ask users</td>
<td><strong>Survey</strong> involving <strong>structured interviews</strong> with visitors to explore mental models, expectations and preferences of commenting in museums. Answers collected on bespoke coding sheets.</td>
<td>Emergent coding following Miles and Huberman (1994) and quasi-statistical methods (Robson, 2002)</td>
<td>Ch. 5</td>
</tr>
<tr>
<td>Model use</td>
<td><strong>Persona and scenario development</strong> based on audience research, survey results (above) and observations during field studies (below) to model uses of SOLs in museums by archetypical users.</td>
<td>Requirements analysis from scenarios following Rosson and Carroll (2003) and Nathan, Klasnja and Friedman, (2007).</td>
<td>Ch. 6</td>
</tr>
<tr>
<td>Ask users</td>
<td><strong>Semi-structured interviews</strong> with museum professionals to explore requirements and preferences from a museum perspective. Data collected via audio recordings, email responses or notes in bespoke coding sheets.</td>
<td>Emergent coding following Miles and Huberman (1994)</td>
<td>Ch. 7</td>
</tr>
<tr>
<td>Prototyping</td>
<td><strong>Early prototype development</strong> to explore and optimise hardware-, software- and interaction designs. Notes on technical development, observations and user feedback in informal settings.</td>
<td>No formal data analysis. Structured reflection on development issues and informal evaluations.</td>
<td>Ch. 8.2</td>
</tr>
<tr>
<td>Lab study</td>
<td>Formative <strong>user-testing and co-design sessions</strong> to evaluate prototypes and inform future designs. Data collected via video recordings (user-testing) and bespoke coding sheets (co-design).</td>
<td>Quasi-statistical methods (Robson, 2002) for quantifiable video data and co-design coding sheets. Emergent coding of users' utterings and open comments following Miles and Huberman (1994).</td>
<td>Ch. 8.4</td>
</tr>
<tr>
<td>Field study</td>
<td><strong>Empirical evaluation</strong> of advanced prototypes in gallery environment. Data collected through <strong>observations, structured interviews, system logs and secondary sources</strong> such as the gallery's visitor numbers.</td>
<td>Statistical methods for system logs, quasi-statistical (Robson, 2002) for quantifiable observations and interview data. Emergent coding of qualitative interview data following Miles and Huberman (1994).</td>
<td>Ch. 8.3, 8.5</td>
</tr>
</tbody>
</table>

*Table 8: Overview of approaches and methods used in the research*
Reflecting a broad consensus in the literature about the need to evaluate ubicomp technologies in the wild, field studies dominate the later stages of the research. Arguments supporting this approach include that important aspects such as device, space, people and time require real use of a system in authentic settings (Abowd and Mynatt, 2000), that users behave more naturally in real-world settings (Hazlewood and Coyle, 2009; Ju and Sirkin, 2010) and that situated user behaviour is fundamentally different from user behaviour in a lab as it puts more emphasis on improvisation and less on following a-priori plans (Abowd, 2012).

3.4 Participants

The research involves users and other stakeholders throughout the process. With respect to the requirements analysis and initial prototype design, participation draws primarily on the informant design model (Scaife et al., 1997), where stakeholders contribute as domain experts. This includes museum visitors who might hold views on institutions' existing efforts to support commenting and how they could be improved. It also includes museum staff with inside knowledge of museums, visitor behaviour and visitor commenting platforms. At later stages, stakeholder participation also draws on the participant design model (Mumford 1997, Spinuzzi, 2005) where users are involved in co-design sessions to evaluate and further develop prototype designs.

Participants include:

- **Potential and actual users of the system**
  Representatives of the primary target audience of SOLs, i.e. museum visitors with a modern smartphone. Audience research by museums (see 6.3) shows this to be a varied and difficult to classify population, while market research by Russel (2011) and Aguirre Johnston and Kohn (2012) indicates that the most likely audience to scan markers with a mobile phone are people between 18 and 34 years of age.
  - For the visitor survey, participants are recruited on the spot among visitors to Fabrica Art Gallery, Brighton and Hove Museums and Tate Modern London.
  - In the context of co-design sessions, participants are recruited among students and staff of the University of Brighton and among visitors to the University of Brighton Art Gallery.
  - In the context of field studies in the wild, participants are recruited on the spot among visitors to Science Gallery Dublin.

- **Domain experts from potential and actual host organisations**
  Potential host organisations that might deploy SOLs include museums interested in social object annotation for audience engagement, marketing (Hsu and Liao, 2011) and social interpretation of exhibits (Gray et al., 2012; Giannachi and Tolmie, 2012; Bagnal et al., 2013).
3.5 Ethical considerations

Ethical considerations concerning the involvement of volunteers in design and evaluation activities are based on Anderson’s (1990) guidelines for using volunteers in research projects. Specific points include:

- **No harm**
  Participants are not pressurised to participate or exposed to the risk of physical harm.

- **Anonymity**
  Data collection and analysis is anonymous.

- **Data protection**
  Collected data is used only in the context of the research and not be made available to third parties without participants' consent.

- **Informed consent**
  Participants are informed about the context and purpose of the research as part of the process of seeking consent.

- **Right to withdraw**
  Participants are made aware that they can withdraw from the research at any time without giving a reason.

With respect to the observation of visitors during field trials, which happens without informed consent in order to observe their natural behaviour towards SOLs, ethical considerations are informed by the British Psychological Society’s code of ethics and conduct. Specifically, the investigator restricts observations "[...] to those situations in which persons being studied would reasonably expect to be observed by strangers, with reference to local cultural values and to the privacy of persons who, even while in a public space, may believe they are unobserved" (British Psychological Society, 2011, p.13).

The research follows the University of Brighton’s Guidance on Good Practice in Research Ethics and Governance (University of Brighton, 2010) with all research studies cleared through the standard ethics approval process prior to commencement.
4 Design space analysis

4.1 Introduction

This chapter first defines and then structures the design space for SOLs in order to support its systematic exploration and provide answers to RQ1 (see 1.4). It defines a design space for SOLs against similar display concepts described in the literature by discussing shared aspects and identifying characteristics that distinguish them from these display concepts. As indicated in Figure 5: Overview of research process (p.66) it then structures the design space in two temporally separate stages:

Stage 1 - at the beginning of the thesis research, during the reconnaissance phase, it provisionally structures the design space by analysing and synthesising taxonomies and heuristics for related display concepts, leading to a draft set of design aspects informed by the literature. This stage is covered in sections 4.3 and 4.4.

Stage 2 - at the end of the thesis research, during the conceptualisation and validation phase, it complements this draft set with additional design aspects emerging from the iterative design and evaluation process, before finally reviewing and consolidating the combined set into ten high-level design aspects for SOLs. This stage is covered in sections 4.5, 4.6 and 4.7.

While there is a large gap between these two stages, with stage 2 drawing on insights from research activities only discussed later in this thesis, they are presented together in this chapter because they belong together thematically and combine literature-based with research-based findings to develop the design space structure.

The chapter ends with a discussion of the ten design aspects and tensions between them, an assessment of the limitations of this design space analysis and a summary of the process and outcomes in the conclusions.

4.2 Distinguishing SOLs from similar display concepts

This section clarifies how SOLs relate to similar display concepts such as ambient displays and interactive public displays and then identifies particular characteristics that distinguish SOLs from these display concepts and define their specific design space.

Besides being public, pervasive, interactive displays, SOLs also qualify as:

- Ambient displays as they "require minimal attention and cognitive effort and are thus more easily integrated into a persistent physical space" (Abowd, Mynatt and Rodden, 2002; p.1)
- Peripheral displays as they are "ubiquitous computing devices that give information to a user without demanding their full attention" (Mathews et al., 2003; p.1)
- Glanceable displays in that "interpreting information on [them] must be very quick and easy" (Matthews, Forlizzi and Rohrbach, 2006; p.2).
As SOLs augment a physical object or space with additional digital information and are not meant to distract attention from the object or place itself, they derive much of their underlying philosophy from key ideas of calm computing (Weiser and Seely Brown, 1996). They primarily target users’ peripheral attention to provide awareness information without substantially increasing cognitive load, but can escalate interaction and move into the audiences’ focused attention when necessary.

Because SOLs are pointless if people don’t engage and interact with them, they share many of the challenges researched in the context of interactive public displays and public access systems. These challenges relate to attracting potential users’ attention, communicating interactivity, and supporting interaction from initial engagement to final disengagement for both single users and groups of users, who might be first-time users without prior experience or repeat users who know how to use the system.

There is considerable overlap between many of these display concepts, e.g. glanceable displays typically are peripheral displays, both can be implemented as ambient displays, which may be public depending on the environment in which they are deployed and interactive depending on their purpose and functionality. Rather than defining distinct types of devices, these labels reflect their specific problem spaces, design goals and research perspectives which set them apart from each other.

The same holds for SOLs, which come with their own problem space and design goals. In addition to aspects shared with ambient displays and interactive public displays, SOLs have a unique set of characteristics not present in that combination in other displays:

1. They relate to a specific physical object or place: The information displayed on a SOL relates to the specific object or place it is “anchored” to (Hansen, 2006). This singular relation eliminates the need to explicitly associate information with a context and thereby reduces cognitive load.

2. They are co-located with the object or place they relate to: SOLs are attached to the physical object they relate to. Presenting information in close relationship with the anchor object increases its spatial deixis and reduces effort and errors when browsing and editing annotations (Hansen, 2006).

3. They are small and peripheral: While the literature is mostly concerned with large, i.e. foot- or yard-scale (Weiser, 1991), public displays that aim to attract as much attention as possible, SOLs are typically small, i.e. inch-scale (ibid), and subordinate to the object they relate to.

4. They are driven by user-generated content: While ambient displays usually display contextual or machine generated data and most public displays show professionally created content in a one-to-many communication model, SOLs are driven by user-generated content and support a many-to-many communication model.

5. They support in-situ content creation: While in-situ content creation can limit the richness, completeness and reliability of information due to practical issues (limited dwell time, awkward text input, more effort to verify and refine contributions), it
also can increase the expressiveness, liveliness, authenticity and relevance of contributions (Weal et al., 2006).

The combination of these characteristics sets SOLs apart from other display concepts described in the literature and shape their specific problem space and research perspective. Together with design aspects shared with ambient displays and interactive public displays they define the design space for SOLs presented in this chapter.

### 4.3 Relevant design aspects from related display concepts

This section reviews existing taxonomies, design heuristics and design space analyses for ambient displays and interactive public displays with regard to their relevance for SOLs.

A key difference between SOLs and ambient displays is that the latter are rarely interactive (Matthews et al., 2003) and usually driven by existing data streams rather than public content contributions. As a consequence, taxonomies and heuristics typically don't cover aspects of interaction or content moderation. In fact, when Mankoff et al. (2003) adapted heuristic evaluation for ambient displays, they modified Nielsen and Molich's (1990) original ten heuristics mainly on the grounds that ambient displays do not involve a task and are not actually "used" but "perceived" (Mankoff et al., 2003). However, ambient displays place great emphasis on peripheral attention and minimising cognitive load, which makes related taxonomies and heuristics highly relevant for SOLs, which should not distract from the object they relate to.

A key difference between SOLs and interactive public displays described in the literature is that the latter are usually not peripheral and/or do not support in-situ content creation. Related taxonomies and heuristics do, however, cover aspects related to attention, engagement, interaction and context, which are relevant for SOLs as they need to attract enough attention to be noticed by potential users and communicate their interactivity to promote engagement.

In order to identify how specific taxonomy dimensions, design considerations and heuristics can inform the design space structure for SOLs, the following work is analysed:

- Ames and Dey's (2002) eleven design dimensions for ambient displays (Table 9)
- Mankoff and Dey's (2003) ten design heuristics for ambient displays (Table 10)
- Brewer's (2004) nine-dimensional taxonomy of ambient displays (Table 11)
- Pousman and Stasko's (2006) taxonomy of ambient information systems (Table 12)
- Tomitsch et al.'s (2007) taxonomy for ambient information systems (Table 13)
- Ballagas et al.'s (2004) considerations for interactive public displays (Table 14)
- Mueller et al.'s (2010) taxonomy of interactive public displays (Table 15)
- Dix and Sas (2011) design aspects for interactive public displays (Table 16)

Not included in this list are the P-Layers framework (Memarovic et al., 2013) as a structured discussion of challenges rather than design characteristics of community-supporting public
Chapter 4 Design space analysis

displays and the various design guidelines for interpretive labels (Screven, 1992; Bitgood, 1996), which focus exclusively on museums, are developed primarily for print labels rather than dynamic displays and are concerned mainly with content and presentation aspects.

<table>
<thead>
<tr>
<th>Ref</th>
<th>Ames and Dey (2002)</th>
<th>Relevance to SOL</th>
</tr>
</thead>
<tbody>
<tr>
<td>AD1</td>
<td>Intrusiveness: Level of intrusiveness should be appropriate to the importance of the displayed information</td>
<td>Relevant for SOLs with respect to integration with the environment and not diverting attention from the object they relate to.</td>
</tr>
<tr>
<td>AD2</td>
<td>Notification: Level of alert when information changes or a state is reached</td>
<td>Relevant to SOLs with respect to interaction feedback and display of state information.</td>
</tr>
<tr>
<td>AD3</td>
<td>Persistence: Time scale and refresh rate at which information is displayed</td>
<td>Less relevant for SOLs, where data changes and display updates are the result of user interaction. A more relevant aspect for SOLs would be latency, i.e. the time it takes for the display to update when content is submitted.</td>
</tr>
<tr>
<td>AD4</td>
<td>Temporal context: Whether the display only shows current information or enables comparisons with historic data or states</td>
<td>Relevant for SOLs as they are based on user-generated content submitted in the past and display actual comments and/or current aggregates such as total number of comments.</td>
</tr>
<tr>
<td>AD5</td>
<td>Overview to detail: Level of detail displayed. Less detail for peripheral attention and more detail for focused attention.</td>
<td>Relevant for SOLs with direct (unmediated) interaction to browse content on the display itself. Less relevant for SOLs with indirect (mediated) interaction, where content browsing and editing happen on the mobile.</td>
</tr>
<tr>
<td>AD6</td>
<td>Modality: Modality the display addresses (visual, auditory, tactile, olfactory, movement). Should aim for modality that is not already overloaded.</td>
<td>Relevant for SOLs with regard to how annotations and/or interaction feedback is presented. Actual designs might be limited by practical constraint and/or social norms.</td>
</tr>
<tr>
<td>AD7</td>
<td>Level of abstraction: Level of abstraction to support easy reading; should be clearly linked to the nature of the information</td>
<td>Relevant for SOLs with respect to increasing readability and making SOLs glanceable (Matthews, Forlizzi and Rohrbach, 2006).</td>
</tr>
<tr>
<td>AD8</td>
<td>Interactivity: Level of afforded interaction appropriate to function with minimal cognitive load</td>
<td>Relevant for SOLs with direct (unmediated) interaction to browse content on the display itself. Also relevant for SOLs with indirect (mediated) interaction with respect to device coupling as an intermediate step to content browsing and editing on the secondary device.</td>
</tr>
<tr>
<td>AD9</td>
<td>Location: Appropriate integration with environment</td>
<td>Relevant for SOLs with regard to integration with environment.</td>
</tr>
<tr>
<td>AD10</td>
<td>Content: Show relevant information</td>
<td>Relevant to SOLs with respect to acceptance, usefulness, attention and engagement.</td>
</tr>
<tr>
<td>AD11</td>
<td>Aesthetics: Pleasing in appearance, in addition to being useful</td>
<td>Relevant to SOLs with respect to integration with the environment.</td>
</tr>
</tbody>
</table>

Table 9: Ames and Dey's (2002) design dimensions for ambient displays and their relevance for SOLs
<table>
<thead>
<tr>
<th>Ref</th>
<th>Mankoff and Dey (2003)</th>
<th>Relevance to SOL</th>
</tr>
</thead>
<tbody>
<tr>
<td>MD1</td>
<td><strong>Sufficient information design:</strong> The display should be designed to convey “just enough” information.</td>
<td>Relevant for SOLs with respect to readability and minimising cognitive load.</td>
</tr>
<tr>
<td>MD2</td>
<td><strong>Consistent and intuitive mapping:</strong> Ambient displays should add minimal cognitive load.</td>
<td>Relevant to SOLs with respect to minimising cognitive load.</td>
</tr>
<tr>
<td>MD3</td>
<td><strong>Match between system and real world:</strong> The system should speak the user’s language, with words, phrases, and concepts familiar to the user.</td>
<td>Relevant to SOLs with respect to learnability and supporting immediate usability (Kules et al., 2004).</td>
</tr>
<tr>
<td>MD4</td>
<td><strong>Visibility of state</strong>: An ambient display should make the states of the system noticeable.</td>
<td>Relevant to SOLs with respect to interaction feedback and display of state information.</td>
</tr>
<tr>
<td>MD5</td>
<td><strong>Aesthetic and pleasing design</strong>: The display should be pleasing when it is placed in the intended setting.</td>
<td>Relevant to SOLs with respect to integration with the environment.</td>
</tr>
<tr>
<td>MD6</td>
<td><strong>Useful and relevant information</strong>: The information should be useful and relevant to the users in the intended setting.</td>
<td>Relevant to SOLs with respect to acceptance, usefulness, attention and engagement.</td>
</tr>
<tr>
<td>MD7</td>
<td><strong>Visibility of system status</strong>: The system should always keep users informed about what is going on, through appropriate feedback, within reasonable time.</td>
<td>Relevant to SOLs with respect to interaction feedback and user control.</td>
</tr>
<tr>
<td>MD8</td>
<td><strong>Easy transition to more in-depth information</strong>: If the display offers multi-levelled information, the display should make it easy and quick for users to find out more detailed information.</td>
<td>Relevant for SOLs with direct (unmediated) interaction with content browsing on the display itself. Less relevant for SOLs with indirect (mediated) interaction, where content browsing and editing happen on the mobile.</td>
</tr>
<tr>
<td>MD9</td>
<td><strong>“Peripherality” of display</strong>: The display should be unobtrusive and remain so unless it requires the user’s attention.</td>
<td>Relevant for SOLs with respect to integration with the environment and not diverting attention from the object they relate to.</td>
</tr>
<tr>
<td>MD10</td>
<td><strong>Error prevention and user control</strong>: Users should be able to distinguish between an inactive display and a broken display.</td>
<td>Relevant to SOLs with respect to interaction feedback and user control.</td>
</tr>
</tbody>
</table>

*Note that heuristics M1-M10 are verbatim quotes from Mankoff and Dey (2003)*

Table 10: Mankoff and Dey’s (2003) heuristics for ambient displays and their relevance for SOLs
Ref | Brewer (2004) | Relevance to SOL
--- | --- | ---
BR1 | **Is the Information specific to a certain group?** The site where a display is installed limits its potential audience, which allows the exploitation of certain group attributes, e.g. shared semantic | Relevant for SOLs in the context of encoding information for specific application domains.

BR2 | **How quickly does the information change?** Rate / frequency of information change | Less relevant for SOLs, where data changes and display updates are the result of user interaction. A related aspect in this context would be latency, i.e. the time it takes for the display to update.

BR3 | **Does past information persist in the present?** Currency of displayed data (history, current) | Relevant for SOLs as they are based on user-generated content submitted in the past and can display actual comments and/or current aggregates such as total number of comments.

BR4 | **How does the ambient information relate to other information at the site?** How well the displayed information integrates with the cognitive environment. | Relevant for SOLs with respect to integration with the environment.

BR5 | **Is the information itself site specific?** If site specific this can be exploited to increase comprehension, e.g. through references to the environment | Relevant for SOLs, which always refers to the specific object or place they are attached to.

BR6 | **If so, is the site mobile or static?** Mobile sites require context-awareness on the fly | Less relevant for SOLs, which are typically attached to static objects or places.

BR7 | **Is the site cohesive or fragmented?** Fragmented sites may require multiple displays, only a subset of which may be perceived by users (impacting on perceived information density and update frequency) | Less relevant for SOLs, which show information about a single object or place.

BR8 | **Is the information already displayed in some way or is it intangible?** Some types of information are already perceivable (e.g., weather) but others are abstract (e.g., stock values). Level to which the display duplicates available information. | Less relevant for SOLs, which always display intangible information such as comments or ratings.

BR9 | **Is the primary purpose of the display to be aesthetic or informative?** Aesthetic emphasis of the display. | Relevant for SOLs with regard to integration with the environment (although SOLs are clearly informative).

*Table 11: Brewer's (2004) taxonomy dimensions for ambient displays and their relevance for SOLs*
<table>
<thead>
<tr>
<th>Ref</th>
<th>Pousman and Stasko (2006)</th>
<th>Relevance to SOL</th>
</tr>
</thead>
<tbody>
<tr>
<td>PS1</td>
<td><strong>Information capacity:</strong> The number of discrete information sources or information &quot;nuggets&quot; presented by the display</td>
<td>Relevant for SOLs as they might display different types of annotations (e.g. comments, ratings) in addition to static information such as object descriptions, calls to action, questions and connection information for mobile devices.</td>
</tr>
<tr>
<td>PS2</td>
<td><strong>Notification level:</strong> The level of alert when information changes</td>
<td>Relevant for SOLs in the context of providing interaction feedback and indicating state information (e.g. low battery, no network).</td>
</tr>
<tr>
<td>PS3</td>
<td><strong>Representational fidelity:</strong> How abstract or direct information is encoded</td>
<td>Relevant for SOLs in the context of making them glanceable (Matthews, Forlizzi and Rohrbach, 2006) and reducing cognitive load.</td>
</tr>
<tr>
<td>PS4</td>
<td><strong>Aesthetic emphasis:</strong> Importance of the aesthetics of the display</td>
<td>Relevant for SOLs with regard to integration with the environment (e.g. when deployed in a museum they should fit in with the overall exhibition design).</td>
</tr>
</tbody>
</table>

*Table 12: Pousman and Stasko's (2006) taxonomy dimensions for ambient information systems and their relevance for SOLs*
<table>
<thead>
<tr>
<th>Ref</th>
<th>Tomitsch et al. (2007)</th>
<th>Relevance to SOL</th>
</tr>
</thead>
<tbody>
<tr>
<td>TO1</td>
<td>Abstraction level: How abstract data is encoded (low, medium, high)</td>
<td>Relevant for SOLs in the context of making SOLs glanceable (Matthews, Forlizzi and Rohrbach, 2006) and reducing cognitive load.</td>
</tr>
<tr>
<td>TO2</td>
<td>Transition: Speed of transition from peripheral to focused attention (slow, medium, fast)</td>
<td>Relevant for SOLs with direct (unmediated) interaction, where content browsing and/or editing happen on the display itself. Less relevant for SOLs with indirect (mediated) interaction, which are designed primarily for peripheral attention as content browsing and editing happen on a secondary device.</td>
</tr>
<tr>
<td>TO3</td>
<td>Notification level: Level of notification when displayed data changes (ignore, change blind, make aware, interrupt, demand attention)</td>
<td>Relevant for SOLs in the context of providing interaction feedback and indicating state information (e.g. low battery, no network).</td>
</tr>
<tr>
<td>TO4</td>
<td>Temporal gradient: Currency of displayed data (history, current)</td>
<td>Relevant for SOLs as they are based on user-generated content submitted in the past and can display actual comments and/or current aggregates such as total number of comments.</td>
</tr>
<tr>
<td>TO5</td>
<td>Representation: Type of display (physical, integrated, 2D screen)</td>
<td>Relevant for SOLs with regard to integration with the environment.</td>
</tr>
<tr>
<td>TO6</td>
<td>Modality: Modality the display addresses (visual, auditory, tactile, olfactory, movement)</td>
<td>Relevant to SOLs from the perspective of lowering cognitive load and/or providing interaction feedback. Actual designs might be limited by practical constraint and social norms.</td>
</tr>
<tr>
<td>TO7</td>
<td>Source: Location of the data source (local, distant, virtual)</td>
<td>Relevant for SOLs with respect to &quot;tetheredness&quot;, i.e. the degree to which content creation and access to content are tied to the physical display (Meramovic et. al., 2013). While SOLs are designed primarily for in-situ content creation, remote content creation (e.g. after a visit) might be an alternative.</td>
</tr>
<tr>
<td>TO8</td>
<td>Location: Location or context of the output device (private, semi-public, public)</td>
<td>Relevant for SOLs with respect to the required robustness.</td>
</tr>
<tr>
<td>TO9</td>
<td>Dynamic of input: How often/fast the displayed data changes (slow, medium, fast)</td>
<td>Less relevant for SOLs, where data changes and display updates are the result of user interaction. A related aspect in this context would be latency, i.e. the time it takes for the display to update.</td>
</tr>
</tbody>
</table>

*Table 13: Tomitsch et al.’s (2008) taxonomy dimensions for ambient information systems and their relevance for SOLs*
<table>
<thead>
<tr>
<th>Ref</th>
<th>Ballagas et al. (2004)</th>
<th>Relevance to SOLs</th>
</tr>
</thead>
<tbody>
<tr>
<td>BA1</td>
<td><strong>Serendipity:</strong> Ability to spontaneously interact with a display. High serendipity equals low threshold of use.</td>
<td>Relevant for SOLs in the context of acceptance and engagement.</td>
</tr>
<tr>
<td>BA2</td>
<td><strong>Portability:</strong> Necessity for, and portability of, tools to interact with the display, e.g. embodied interaction equals high portability.</td>
<td>Relevant for SOLs in the context of acceptance and engagement.</td>
</tr>
<tr>
<td>BA3</td>
<td><strong>Sanitation:</strong> Cleanliness of interaction technique (in terms of health considerations).</td>
<td>Relevant for SOLs with direct interaction. Not relevant for SOLs with indirect interaction as they don’t require physical contact.</td>
</tr>
<tr>
<td>BA4</td>
<td><strong>Dexterity:</strong> How many hands are required for operation.</td>
<td>Relevant for SOLs with respect to interaction complexity, engagement, level of user control.</td>
</tr>
<tr>
<td>BA5</td>
<td><strong>Multi-user:</strong> Support for multiple simultaneous users.</td>
<td>Relevant for SOLs with respect to engagement in busy environments.</td>
</tr>
<tr>
<td>BA6</td>
<td><strong>Physical security:</strong> Protection from vandalism and theft.</td>
<td>Relevant for SOLs deployed in public and semi-public places.</td>
</tr>
<tr>
<td>BA7</td>
<td><strong>Information security and privacy:</strong> Security and privacy when interacting with the public display.</td>
<td>Less relevant for SOLs, as they involve user-generated content rather than any sensitive or personal information.</td>
</tr>
<tr>
<td>BA8</td>
<td><strong>Social acceptability:</strong> Acceptability of interaction technique with regard to social norms.</td>
<td>Relevant for SOLs with respect to acceptance and engagement.</td>
</tr>
<tr>
<td>BA9</td>
<td><strong>Interruptability:</strong> Level to which the system copes with short-term interrupted interactions</td>
<td>Relevant for SOLs with direct interaction where the display screen doubles as and interaction surface. Less relevant for SOLs with indirect interaction where interaction happens on the user’s device.</td>
</tr>
<tr>
<td>BA10</td>
<td><strong>Intentional vs. unintentional interaction:</strong> Refers to explicit and implicit/unnoticed interaction</td>
<td>Less relevant for SOLs, where interaction is always explicit and intentional.</td>
</tr>
<tr>
<td>BA11</td>
<td><strong>Maintenance:</strong> Amount of regular service the system needs.</td>
<td>Relevant for SOLs with respect to acceptance by host organisations.</td>
</tr>
</tbody>
</table>

*Table 14: Ballagas et al.’s (2004) considerations for interaction with public displays and their relevance for SOLs*
Chapter 4 Design space analysis

<table>
<thead>
<tr>
<th>Ref</th>
<th>Mueller et al. (2010)</th>
<th>Relevance to SOL</th>
</tr>
</thead>
<tbody>
<tr>
<td>MU1</td>
<td><strong>Mental model:</strong> Four mental models are identified including poster (display of content), window (link to other location), mirror (reflect audience or location) and overlay (add content to present context).</td>
<td>Less relevant for SOLs as there are no established mental models for applications involving small peripheral displays.</td>
</tr>
<tr>
<td>MU2</td>
<td><strong>Interaction modality:</strong> Wide range of interaction types including presence, position, pose, facial expression, gaze, speech, gesture, remote control, keys and touch.</td>
<td>Relevant for SOLs with regard to acceptance and engagement. A key distinction in this context is between direct (unmediated) and indirect (mediated, e.g. mobile) interaction. Actual designs might be limited by practical constraint and/or social norms.</td>
</tr>
<tr>
<td>MU3</td>
<td><strong>Type of supported interaction:</strong> Level of user’s awareness and intent when interacting with the display, based on a continuum between implicit and explicit interaction.</td>
<td>Less relevant for SOLs, which by default involve explicit interaction. Future uses may benefit from implicit interaction, e.g. with regard to engagement or personalisation.</td>
</tr>
</tbody>
</table>

* Additional design dimensions identified by Mueller et al. (2010) include whether the display supports single, pairs or multiple users and whether it is installed in a public, semi-public or private environment. However, based on the argument that these criteria are "application rather than interaction-centric" (ibid, p.1291), they are not included in their taxonomy.

Table 15: Mueller et al.’s (2010) taxonomy dimensions for interactive public displays and their relevance for SOLs
## Chapter 4 Design space analysis

### DS1 Physical display size:
Weiser’s (1991) inch, foot and yard scales they propose poppyseed (1/12 inch) and perch (5 ½ yards) scales. Terrenghi, Quigley and Dix (2009) later add to that the chain (22 yards) scale.

Relevant for SOLs with regard to obtrusiveness and information capacity. Must be considered together with observation/interaction proximity and contrast to the environment.

### DS2 Interaction device uses:
Range of possible uses for personal devices in combination with a public display, including selection, text input, data storage, identification, sensing and as a display surface.

Relevant for SOLs with indirect (mediated) interaction.

### DS3 Social context and audiences:
Roles and awareness of audiences, including witting/unwitting participant, bystander and passer-by.

Relevant for SOLs in the context of attention and engagement.

### DS4 Participant-audience conflicts:
Conflicts relating to content or pace when an individual controls a public display simultaneously watched by others.

Relevant for SOLs with direct (unmediated) interaction where the interacting user might block others' interaction. Less relevant for SOLs with indirect (mediated) interaction as users have no control over pace or content on SOLs.

### DS5 Spatial context:
Access to (public, semi-public, semi-private) and integration with (no, weak, close, dynamic coupling) the environment.

Relevant for SOLs with respect to attention, engagement and required level of robustness. Related to T08

### DS6 Multiple device interactions:
Level to which the private device forms a multi-device system with the public display (alternative, secondary, coherent interface).

Relevant for SOLs with indirect (mediated) interaction where the user’s private device acts as secondary display.

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Table 16: Dix and Sas' (2011) design aspects for interactive public displays and their relevance for SOLs
4.4 Synthesis of design aspects from related display concepts

This section synthesises relevant design aspects [DA\text{n}] identified above and groups them into four categories for greater clarity: content, presentation, interaction and integration with the environment.

**Content**

[DA1] **Domain specificity**: Whether the information is specific to a certain audience, which allows the exploitation of shared semantics [BR1]. Related to "match between system and real world" [MD3], which recommends that systems use words and concepts familiar to the user. While the main content on SOLs (e.g. comments, ratings) is user generated and therefore beyond the designer's control, the language used for supporting information and user interface elements can be tailored to fit specific application domains.

[DA2] **Information density**: Number of discrete information "nuggets" or information sources presented on the display [PS1]. SOLs may display different types of user-generated content (e.g. comments, ratings) as well as other information such as an object description, call to action or ID (e.g. QR code). Information should be relevant [AD10], useful [MD6] and "just enough" [MD1].

**Presentation**

[DA3] **Modality** (e.g. visual, auditory, tactile, olfactory) addressed when displaying information and giving interaction feedback [AD6, TO6]. Relevant to SOLs with respect to attention, obtrusiveness and acceptance. Actual designs might be limited by practical constraints and/or social norms of the specific environment.

[DA4] **Level of abstraction**: How abstract or direct information is encoded [AD7, TO1]. Closely related to "representational fidelity" [PS3] and "consistent and intuitive mapping" [MD2]. Relevant with respect to learnability and cognitive load.

**Interaction**

[DA5] **Serendipity**: Ability to spontaneously interact with the display without the need for preparatory steps (e.g. device setup, instructions, login) [BA1]. Relevant with respect to engagement, in particular for first-time users. Related to [DA7].

[DA6] **Technological inclusiveness**: Do users need specific hardware [BA2], software, network access or technical knowledge to interact with the display? Such requirements, and the way how they are communicated and explained, impact on users' actual and perceived ability to interact with a display.

[DA7] **Social acceptability** of interaction technique [BA8]. Relevant for SOLs deployed in public or semi-public environments which may have specific social norms (e.g. museum). Potential users might not engage if it involves embarrassment.
Chapter 4 Design space analysis

[DA8] **Multi-user support** [BA5]. Relevant with respect to engagement. Displays without multi-user support require potential users to wait when they are used somebody else, which can lower engagement rates.

[DA9] **Interaction modality** [MU2]. Relevant with respect to how people engage and interact with SOLs. Informs interaction design at fundamental level.

[DA10] **Interaction control**: Level of afforded interaction [AD8], both in terms of functionality (e.g. read, select, write, program) and input granularity (e.g. select predefined options, free text input, free-hand drawing, media support, etc.)

[DA11] **Visibility of state**: How users are kept informed about the state [MD4] and status [MD7] of the display. Relevant with respect to supporting interaction and preventing errors [MD10].

**Integration with the environment**

[DA12] **Access**: (public, semi-public, semi-private, private) [DS5, TO8]. Impacts on social context and potential audiences [DS3]. Relevant with respect to acceptance, engagement and robustness.

[DA13] **Fit with information environment**: How the displayed information integrates with other information at the site [BR4] and whether it duplicates information already displayed in some other way [BR8].

[DA14] **Aesthetic emphasis**: Importance of the aesthetics of the display [AD11, MD5, BR9, PS4]. Relevant with respect to integration with the environment (e.g. style conventions or constraints in certain environments). Related to [DA15].

[DA15] **Peripherality**: How peripheral or obtrusive the display is [AD1, MD9]. One factor in this context may be the display size [DS1]. Relevant with respect to integration with the environment and not distracting from physical object.

[DA16] **Security**: Protection from vandalism and theft [BA6] and privacy when interacting with the display [BA7]. Relevant for SOLs with respect to deployment in public and semi-public places.

[DA17] **Maintenance**: Amount of regular service the system needs [BA11]. Relevant with respect to deployment and operating costs.

### 4.5 Additional aspects emerging from design and evaluation activities

The combination of characteristics that set SOLs apart from other display concepts (see 4.2) has a number of design implications which are only marginally, if at all, covered in existing taxonomies for ambient displays and interactive public displays. This section discusses these additional aspects, which are informed directly by the user-centred design and evaluation of SOL prototypes discussed in the following chapters.
Chapter 4 Design space analysis

SOLs are conceptualised as an independent layer of functionality that can add to, and complement, existing engagement efforts in museums and does not require deep integration with existing workflows and IT infrastructure. This lightweight approach makes them quick and easy to deploy, allowing for short-term in-situ trials and reducing risks for organisations adopting the system. An important design implication of this approach is that SOLs must be configurable and customisable to meet host organisations’ requirements and preferences (Chapter 7) and integrate with a wide range of exhibition designs (see 8.3.2 and 8.5.2) without requiring custom development. Specific customisation and configuration options for SOLs are discussed in more detail in Winter (2014b).

[DA18] **Plasticity:** The level to which the display can be configured to meet host organisations’ needs and preferences. This includes technical configurability (e.g. object registration, networking mode, battery or mains operated, etc.), functional configurability (e.g. comments or ratings) and interface configurability (e.g. terminology, prompts, images, etc.). It also includes whether configuration changes can be triggered remotely and automated or require in-situ interaction.

While interviews with museum professionals indicate strong support for SOLs’ lightweight approach, they also suggest that some level of optional integration would be welcome, e.g. to display visitor comments on the museum’s website or post them on social media to help promote the exhibition (see 7.3.5). In this context, museums strongly prefer open technologies and data formats to avoid technical lock-in and to ensure that SOLs integrate well with other systems (ibid). In addition to the technical perspective on openness, there also is an interaction perspective. Memarovic et al. (2013) discuss "tetheredness" as a design dimension that can limit content creation and browsing to physical co-location with the display or allow remote ("free to roam") content access. While visitor interviews indicate a strong preference for the latter (see 5.3.3), museum professionals see "untethered" access as an optional extra rather than a necessity (see 7.3.3).

[DA19] **Openness:** From a technical perspective, the level to which the system uses open technologies and data formats, integrates with other platforms (e.g. museum website; social media channels), and allows access to its content from outside the system (e.g. through an API). From an interaction perspective, whether users need to be co-present with the SOL in order to read or contribute comments or whether they can access SOLs remotely.

As SOLs are deployed in public or semi-public spaces, it is important for host organisations to have control over the user-generated content displayed on them. Interviews with museum professionals indicate a wide range of attitudes towards moderation (see 7.3.1), with some advocating pre-moderation due to public liability and others preferring post-moderation arguing that it is acceptable to remove offensive content in a reasonable timeframe. The majority of museum professionals prefer a hybrid approach combining post-moderation with community monitoring (ibid). From a user perspective, crucial aspects include how long the moderation process delays comments showing up on the system and how transparent and fair the moderation process and criteria are (see 5.3.6).
Content moderation: Whether content on the system is moderated and if so, if it is pre- or post-moderated and if the moderation is automated (e.g. based on a black-list of words) or carried out by humans, which may include museum staff and/or community members.

While SOLs were originally conceptualised as simple displays that delegate interaction to a user’s mobile device, user research suggests that it would be beneficial to offer at least some functionality via direct interaction on the SOL display. Visitor interviews identified directness of interaction and ease of use as key criteria in their assessment of commenting mechanisms (see 5.3.3). Museum professionals pointed out that direct interaction would help to engage visitors without a mobile device or unwilling to use it in this context (see 8.3.4.3). A field trial involving prototypes supporting only mobile interaction showed that many visitors assume displays to have touch screens and, after probingly touching the screen without getting a response, make no other attempts to interact with SOLs (see 8.3.3), while a second field trial involving prototypes supporting both mobile and touch interaction, showed touch interaction to be a popular feature with visitors (see 8.5.4.2).

Interaction Directness: Whether and how the interaction is mediated, ranging from direct interaction (e.g. touch screen, gestures), to mediated interaction (e.g. mobile device coupled to the display). Hybrid approaches may distribute functionality between different interaction modes, either exclusively or redundantly, giving users a choice of how they would like to interact.

The ability to identify users, either on a technical level or through explicitly user-created identities, and to relate interaction and submitted content to them, has wide-ranging implications for the functionality and operation of SOLs. Examples include the option to edit or correct one's own comments after submission, the display of names or other identifying markers together with comments to enable users to refer to each other and the option for visitors to build up profiles and develop a reputation, which can improve content quality and motivate longer-term engagement with the system (Benkler, 2004). At the same time, requiring visitors to register and log in in order to participate conflicts with the idea of serendipity [DA5] and most museum professionals advise to avoid mandatory registration and login (see 7.3.2).

User identification: Whether and how the system identifies users and the content they submit. This can range from no identification (anonymous system) to technical identification (e.g. via a device identifiers or cookies), to explicitly created user identities requiring registration and login and fully developed profiles that integrate with existing online identities.

A key aspect of SOLs is that they relate to a physical object or place. This link is established via an object ID (Kindberg, 2002), which administrators enter into the SOL configuration screen (see Appendix B). In order for end-users to recognise which object a SOL relates to, it should provide suitable human-readable information on the SOL display and in the related mobile application.
Chapter 4 Design space analysis

[DA23] **Cognitive link to anchor object:** How the cognitive link between SOL and physical object or place is established. This can range from implicit association based only on proximity to explicit association by displaying an object ID, title or name or an image of the object. (If the link is established by replicating or referring to information already available in the environment, this aspect directly relates to [DA13]).

Host organisations, developers and researchers all have an interest in gaining a detailed understanding of how users interact with SOLs. Technical logging of users' interactions can provide insightful information in this context. When coupled with suitable tools for visualisation and analysis (see 8.5.3.2.3), this can inform changes to the design and placement of SOLs. Combined with tools for remote customisation (see DA18) such functionality enables host organisations to adapt and optimise SOLs in a live environment.

[DA24] **Interrogability:** The level to which the display records user interactions and technical events (basic to detailed), makes them available for analysis (local to remote, delayed to real-time) and offers suitable tools (basic to comprehensive, static to interactive) to interrogate the data and inform adjustments to content presentation and functionality (see Plasticity above) to maximise engagement.

This latter design dimension also resonates with calls in the literature to develop methods and tools that help to better understand how people interact with such technologies in public settings (Hazlewood and Coyle, 2009).

### 4.6 Review and consolidation

This section reviews and consolidates the design aspects discussed above in order to reduce overlaps and increase clarity in line with Fishkin's (2004) train of thought that "the more dimensions [an explanatory structure has] the greater the descriptive power, but the greater the over-head, the lesser the simplicity and clarity" (ibid, p.348).

**Merged aspects**

[DA1] Domain specificity + [DA18] Plasticity

The domain specificity of a display is subordinate to its plasticity as a means to dynamically configure and customise its various design aspects. These aspects are therefore merged into the single design aspect **Plasticity**.


All of these aspects are concerned with how users interact with SOLs and what opportunities and limitations the interaction mode entails. As social acceptability, multi-user support and interaction directness depend to a large extent on display modality and
interaction modality, these aspects are subsumed into a single design aspect Interaction modality.

While serendipity is generally concerned with how casually users can engage with SOLs, technological inclusiveness addresses technological barriers and user identification addresses both procedural and privacy barriers when engaging with SOLs. While these aspects also have other far-reaching implications, we focus on user experience and therefore subsume them into the single design aspect Ease of engagement.

While interaction control focuses primarily on user input, visibility of state complements this aspect with system output. Without information about the system state it is impossible to make effective use of functionality. We therefore subsume these aspects into the single design aspect User control.

All of these aspects are concerned with the information displayed by the SOL, including the amount of information, how it is encoded and how it complements, duplicates or refers to other information present in the environment. These aspects are therefore merged into the single design aspect Information presentation.

Unlike ambient displays, where aesthetic emphasis is a design dimension in its own right, this aspect is relevant for SOLs primarily in the context of fitting in with a target environment and not distracting from the physical object or place they relate to. We therefore merge these aspects into the single design aspect Conspicuousness.

All of these aspects relate to how much SOLs need looking after once they are deployed. Understanding access as a variable determining the level of required security and maintenance issues like battery life as robustness in terms of self-sufficiency, we can merge these aspects into the single design aspect Robustness.

4.7 Ten design aspects
This section presents ten high-level design aspects for SOLs, drawing on an analysis of existing taxonomies and design heuristics described in the literature, design aspects
emerging from the iterative design and evaluation of SOLs, and a review and consolidation process presented in the previous section. The resulting design aspects are:

1. **Openness**
   From a content perspective, this includes whether content is locked into the system or can be used in other contexts, including future times, via open technologies and data formats. From an interaction perspective, it includes whether users need to be co-located with the display to create/access content, how the system integrates with their personal communication habits and whether they need any specific equipment or technical skills to use it. With regard to transparency, it refers to an organisation's practices and policies around commenting and content and how these are communicated to users.

2. **Plasticity**
   The level to which the system can be customised, configured and scaled to meet the requirements of host organisations and specific deployments. This includes presentation configurability (e.g. terminology, prompts, artwork, layout, etc.), functional configurability (e.g. submit comments and/or ratings), technical configurability (e.g. support for different power and networking options) and physical configurability (e.g. range of casings and mounting options). Plasticity considerations also include whether the system is scalable and supports ad-hoc registration and creation of object IDs and digital resources.

3. **Interrogability**
   From a research and evaluation perspective, the level to which the system provides engagement and interaction statistics that can inform adjustments in existing and future deployments (see plasticity above). This includes the quantity and quality of analytics data, whether data is available in real-time and/or historically and to what extent the data can be interrogated and analysed. From an administration perspective, the level of support for technical status monitoring, e.g. whether individual displays indicate technical problems to gallery staff and/or users, and to what level administrators can centrally monitor the status of displays.

4. **Ease of engagement**
   The level to which the system supports spontaneous interaction. This includes whether the system requires preparatory steps to initiate interaction (e.g. device setup, registration, login), whether it provides options for lightweight engagement (e.g. rating comments rather than creating comments) and whether information is provided that explains and frames the interaction. Also includes ergonomic aspects that determine how easy it is to physically interact with the system.

5. **Interaction modality**
   Refers to the interaction modes and technologies supported by the system, ranging from direct (e.g. touch, gesture) to mediated interaction (e.g. mobile device), and how functionality is distributed between different interaction modes, ranging from
redundant to exclusive functionality. Considerations in this context also include support for multi-user interaction and social acceptability of interaction modes.

6. **User control**
   The level of control people have when using the system. This includes control over how much personal information users provide (e.g. registration, meta information, tracking), control over the format and topic of their contribution (e.g. predefined options or free text), control over content once it is submitted (e.g. ability to edit or delete content) and agency in the community of people using with the system (e.g. reply to, rate or flag comments). User control also includes usability aspects such as interaction feedback and visibility of system state.

7. **Content moderation**
   How user-generated content submitted to the system is monitored and moderated. This includes whether content is pre-, post- or on-request-moderated, how long it takes for content to be displayed or removed, how responsibilities are distributed between users and host organisations and how the system supports the monitoring and moderation process with regard to effectiveness, efficiency and user experience.

8. **Information design**
   How much information is displayed, how it is encoded and presented, and how it integrates with other information at the site. Of particular interest in this context are *glanceability* (Matthews, Forlizzi and Rohrbach, 2006), readability, learnability and persuasiveness to encourage engagement and support first-time and repeat users.

9. **Conspicuousness**
   The level to which the display attracts users' attention, i.e. how prominent or peripheral it is. Factors in this context include the physical design (e.g. size, casing, colouring, screen type, etc.) and the placing of displays which both influence how well it blends into the environment or stands out to be noticed. Conspicuousness is not a discrete quality of the display itself but must be considered in context with other factors determined by the environment.

10. **Robustness**
    Relates to physical robustness (e.g. protection from vandalism and theft), technical robustness (e.g. resilience against power loss and dropped network connections) and interaction robustness (e.g. automatic timeouts, protected functionality). Also relevant in this context is how well the system supports the administration and maintenance of deployed displays to ensure sustained, interruption-free operation.

### 4.8 Discussion

The ten high-level design aspects presented here go beyond existing display taxonomies and design heuristics by making *plasticity* and *interrogability* fundamental design concerns.
This reflects a shift in perspective from developing a bespoke system optimised for one specific context, as so often is the case in research prototypes exploring new technologies in a specific environment or domain, to developing a generic system that can be adapted and customised for many different contexts and environments. It also reflects a shift in development approach from targeting a "finished" or "optimal" design to instead aiming for a highly adaptable system in which aspects such as information-density, -representation and -architecture become adjustable parameters rather than first-order design dimensions. Being able to interrogate displays in real-time and adjust display parameters based on actual engagement and interaction data provides a way to optimise them for specific locations, times and audiences not possible with static designs.

Some of the tensions created by conflicting design goals for SOLs relate to multiple design aspects and highlight areas of interest for research. These include:

- SOLs should not divert attention from the object they relate to but at the same time be noticeable and encourage engagement. While the former demands blending in with the environment and targeting users' peripheral attention, the latter relies on being conspicuous enough to inform and engage users. This design tension mainly relates to (9) Conspicuousness but should also be investigated with respect to (8) Information Design, which might impact on both attention and engagement (see 8.3.5.1, 8.5.4.1 and 8.5.4.2 for related findings).

- SOLs should reach a broad audience and be easy to use and engage with. While the former requires the use of standard technologies that have reached market saturation, the latter is better served with newer technologies that are optimised for physical-mobile interaction but only available on the latest handsets. This design tension relates primarily to (4) Ease of engagement but should also be investigated with respect to (1) Openness, (5) Interaction modality and (8) Information Design, which might impact on whether and how users engage with SOLs (see 8.3.5.1, 8.5.4.2 and 8.5.4.3 for related findings).

- SOLs should lower barriers to engagement but at the same time protect both organisations and users from offensive content. While the former suggests anonymous contributions and post-moderation, the latter is easier to accomplish with registered users and pre-moderation. This design tension relates primarily to (7) Content moderation but must also be investigated with respect to (6) User control and (4) Ease of engagement, which might impact on users' willingness to engage with and contribute content (see 5.3.4, 5.3.6, 7.3.1 and 8.3.3.3 for related findings).

These design tensions need special attention when developing SOLs. As related aspects might depend on host organisations' needs and preferences, they should not only be addressed in the requirements analysis for the generic platform but also when considering specific configuration options for particular SOL deployments.
4.9 Limitations

With regard to validity, the design space analysis is grounded in literature on ambient and interactive public displays and complements design aspects of these display concepts with aspects emerging from a systematic design and development process that draws on user research and empirical evaluations of SOL prototypes in realistic settings. While structuring a design space is necessarily arbitrary and subjective to a certain level, the reasoning behind each step in this process is described in detail to invite scrutiny and aid interpretation.

With regard to transferability, some of the identified design aspects are shared with, and informed by, taxonomies and design heuristics for similar display types from the outset. Others, relating to more specialised characteristics, such as being interactive or driven by user-generated content, can be applied to display concepts sharing these characteristics even if the design space structure as a whole may not be suitable. Two of the identified aspects, plasticity and interrogability, are highly transferable and apply to any interactive system that might benefit from research-driven customisation and optimisation.

4.10 Conclusions

This chapter provides answers to research question RQ1, asking how the design space for SOLs can be defined and structured.

Defining the design space for SOLs involved in a first step delineating them against similar display concepts by identifying overlaps and differences. Just as categorisations in the literature of displays as ambient, public, peripheral or glanceable reflect a research perspective, the delineation of SOLs reflects their specific problem space and identifies a set of characteristics not present in that combination in other displays. In particular these include that SOLs are small (inch-scale), relate to a specific physical object or place, are co-located with the object or place they relate to, have mechanisms to create content in-situ and are driven by user-generated content.

Structuring the design space involved analysing and synthesising existing taxonomies and design heuristics for ambient and public displays, complementing them with SOL-specific design aspects emerging from the requirements analysis and iterative development, and then reviewing and consolidating the resulting list of attributes into a set of 10 high-level design aspects. The design aspects mark a departure from the taxonomies and design heuristics reviewed in this chapter as they conceptualise displays as generic, customisable systems taking advantage of dynamic configuration options (plasticity) and informed by real-time engagement data (interrogability), rather than bespoke systems with static design features optimised for a particular context. Potential advantages of this shift in perspective include making development efforts more sustainable as prototypes can be reused and adapted, and making research efforts more comparable as the same system can be evaluated in different contexts and environments.
In addition to producing a set of design aspects that structure the design space, the discussion also attended to a number of design tensions in SOLs, which need to be addressed not only in the overall system design but for each individual deployment with regard to the particular environment and the host organisation's needs and preferences.
5 Visitor perspective on commenting in museums

5.1 Introduction

This chapter explores visitors’ preferences, expectations and conceptual models of commenting in museums with a view to informing the development of SOLs as a social commenting platform for that domain. Focusing on the visitor perspective rather than the museum perspective, it aligns with the user-centred design approach of the research and sheds light on aspects of commenting not sufficiently covered in the literature.

Commenting in museums, as feedback to the institution, as interpretation of exhibits or as contribution of information to data sets around objects, is a well-established way to engage audiences and encourage participation. It provides visitors with opportunities to reflect on exhibits and their experience in the gallery space, and thus plays into museums’ agenda as places for meaning-making and informal learning (Falk and Dierking, 2000). In addition to

Figure 6: Examples of common commenting mechanisms in museums, including visitor books (a), comment cards (b), feedback boards (c), feedback screens (d), website comments (e) and social media comments (f).
advancing the institution's educational goals, visitor comments can generate valuable data for the museum and help to reframe its relationship with visitors by signalling "that the museum is interested in them as thinking beings" (Adams and Stein, 2004, p.3). Reflecting this broad range of benefits, it comes as no surprise that commenting is a standard form of participation in heritage organisations. Many museums offer visitors the opportunity to record their comments in a visitor book. Many other commenting mechanisms have emerged over time, ranging from analogue to digital, from pre-moderated to post-moderated and from in-gallery systems to online platforms. Examples include comment cards, feedback boards, feedback screens, website comments and social media comments (Figure 6).

The literature discusses a range of museum- and computing-related aspects of commenting systems. Various authors report on the introduction and evaluation of new digital systems (e.g. Gammon and Mazda, 2000; Stevens and Toro-Martell, 2003; Hsu and Liao, 2011; Seirafi and Seirafi, 2011; Gray et al., 2012; Giannachi and Tolmie, 2012), discuss the value, quality and moderation of content generated by people using these systems (e.g. Alexander, 2000; Russo et al., 2008; Gray et al., 2012) and examine visitor comments as a research resource (e.g. Macdonald, 2005).

By contrast, visitors' views on commenting systems in museums and their mental models of what happens to comments once they are submitted are largely unexplored. Which commenting mechanisms do visitors prefer and why? Who reads comments submitted to a museum? Might they be censored or edited? Are they being archived, and if so, for how long? Might comments be re-used at some point or re-produced in other media or contexts? Would the comment author have a say in that? Who owns the comments submitted to a museum? Little is known about museum visitors’ views on these questions.

In order to address this gap, a survey was carried out to explore visitors’ expectations, preferences and mental models of commenting in museums. The survey involved 104 structured interviews with visitors at three different arts organisations:

- **Fabrica Art Gallery**: "Fabrica is a small contemporary art gallery housed in a former Regency church in the centre of Brighton. [...] The gallery often commissions art works specific to the gallery space and runs a wide range of activities to support its exhibition programme [...]. Fabrica attracts a varied audience made up of local residents and tourists visiting Brighton for the weekend." (Visit Brighton 19)

- **Tate Modern**: "Tate Modern is the national gallery of international modern art [...] in a disused power station in the heart of London [...] permanent collection is complemented by a continuous programme of temporary exhibitions. [...] most-visited modern art gallery in the world, with an international audience of around 4.7 million visitors per year." (Tourist Information UK 20)

• **Brighton Museum**: "Brighton Museum houses one of the most important and eclectic collections outside national institutions. [...] innovative galleries - including fashion and style, 20th century art and design, and fine art - feature exciting interactive displays appealing to all ages. In addition to the permanent galleries, there is a continuing programme of temporary exhibitions." (Visit Brighton ²¹)

While the primary purpose of the survey was to examine the problem space for SOLs from a museum visitor perspective and thereby inform the requirements analysis, the study was designed to deliver a range of general insights about visitors' preferences and mental models, which might be equally relevant to other research efforts investigating commenting in museums. For instance, results relating to visitors' views on content ownership and informed consent also fed into an unrelated, funded research project exploring game-based crowd-sourcing in the cultural heritage sector (Winter et al., 2014).

### 5.2 Method and instrument

The survey involved structured visitor interviews designed to last between 15-20 minutes. Actual duration of interviews was 26 minutes on average. The interviewer followed a fixed script and took notes on a bespoke coding form designed to quickly mark common answers (determined during a pilot study) while also providing space for unexpected responses and verbatim quotes. Following advice in Valenzuela and Shrivastava (2008), the researcher reviewed the coding sheet immediately after each interview to supplement and clarify notes.

The interviews took place in the gallery space (Fabrica Art Gallery, Brighton Museum) and concourse areas (Tate Modern) of participating organisations rather than in a neutral location or lab environment. This ensured that all interviewees were actual museum visitors and helped participants to contextualise interview questions. Carrying out the interviews in-situ also had practical advantages as there was no need for extra scheduling or travel for participants taking part in the study.

The survey instrument, including information leaflet, consent form, script, interview questions, coding sheet and support materials (see Appendix D) was developed over several iterations. While originally conceived as an online survey, early discussions suggested that a structured interview might be better suited to the explorative character of the study as it allows for probing and follow-up questions and enables the interviewer to gain additional insights on aspects not anticipated in the questionnaire.

#### 5.2.1 Pilot interviews

Advanced versions of the survey instrument were piloted with six participants recruited among staff and students at the University of Brighton. The pilot sample included both

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male and female participants ranging from 29 to 63 years, with various educational backgrounds (Higher Education, Further Education), first languages (English, non-English) and interests in museums (one visit per month to one visit per year), reflecting at least some of the diversity of actual museum visitors and likely participants in the survey.

The pilot interviews informed critical changes in the final iterations of the survey instrument. In particular, they helped to amend and streamline the interview script; adjust timings based on how much time was needed to pose and explain questions and to which degree interviewees were able to engage with questions; refine the wording of questions to ensure that they were understood as intended; finalise the sequence of questions to create context as the interview progresses and inform follow-up questions; give an idea of likely answers and dichotomies that helped to optimise the coding sheet. Actual interview responses from the pilot study were discarded and not included in the evaluation results.

5.2.2 Interview script

The interviewer followed a script with a fixed sequence of actions and questions to ensure consistency across sessions and institutions. Potential participants were approached in a friendly, non-threatening way that enabled them to decline without taking or causing offence. If they showed interest, they were informed about the context and content of the research study, given an information leaflet and had opportunity to ask questions and have them answered by the interviewer. If participants then agreed to take part in the study, they were asked to read and sign a consent form before the interview took place.

Once consent was given, the actual interview began with the researcher going through a series of questions, providing large-print information materials (e.g. images of feedback mechanisms) at fixed points and noting answers in a coding sheet. The last section of the interview, which asks for demographic information, was not administered but filled in by interviewees themselves in order to avoid any perception of intruding their privacy.

After the structured interview, the interviewer thanked participants and asked them if they had any additional comments or questions not covered in the interview. Interviewees were offered the opportunity to stay in touch with the researcher and be notified about the results of the survey. A separate contact sheet asking for name and email address was provided for this purpose to ensure anonymity of the interview responses.

Once participants had left, the interviewer immediately began reviewing the interview notes while the memory of participants' responses was still fresh. This included expanding on short notes to explain their context and meaning, filling in additional information not written down during the interview, and in some cases clarifying handwriting that might otherwise be difficult to decipher later on. Other post-interview tasks included updating the response tally, putting away the filled-in coding sheet and consent form, and getting ready for the next interview with a new coding sheet and consent form.
5.2.3 Interview structure

The interview was divided into eight sections:

1. Communication during and after museum visits, including inclination to read object labels and/or discuss their experience with others in person or online.
2. Preferences for different commenting mechanisms. Visitors were shown images of six common feedback mechanisms to support this section.
3. Interest in additional information about authors when reading comments and inclination to provide such information when submitting comments.
4. Expectations and preferences on who should read submitted comments.
5. Assumptions and preferences on whether museums suppress or remove certain visitors comments, what the criteria would be and who makes such decisions.
6. Assumptions and preferences on archival practices for user-generated content, e.g. how long comments are stored and whether they are digitised by the museum.
7. Views on intellectual property rights, informed consent and reuse of comments.
8. Demographic information, filled in by participants.

5.2.4 Sampling

Given that the interviews were carried out in-situ and involved actual museum visitors, the survey used convenience sampling (Robson, 2002), including visitors most easily approached and willing to take part in a structured interview. In order to maximise the range of views and insights gathered in interviews and reduce bias, some common strategies from probability sampling were employed as discussed in the following section.

5.2.5 Reducing bias

In order to reduce coverage bias, participating arts organisations varied in a range of aspects influencing their specific audience composition (Table 17). In addition, interviews were carried out on different days of the week, including work days, holidays and weekends, which are likely to draw different visitors.

<table>
<thead>
<tr>
<th>Fabrica Art Gallery</th>
<th>Tate Modern</th>
<th>Brighton Museum</th>
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<tbody>
<tr>
<td>small</td>
<td>large</td>
<td>medium</td>
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<tr>
<td>city</td>
<td>metro</td>
<td>city</td>
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<tr>
<td>local</td>
<td>international</td>
<td>regional</td>
</tr>
<tr>
<td>art gallery</td>
<td>art museum</td>
<td>mixed</td>
</tr>
</tbody>
</table>

Table 17: Participating institutions
In order to reduce selection bias when approaching potential interviewees in the museum, the researcher tried to balance between different age ranges, between female and male visitors and between visitors who attended on their own or in groups.

In order to reduce response bias, which involves participants not being truthful for various reasons, e.g. when trying to give "the right" answer to a question (Turnock and Gibson, 2001; Robson, 2002), the interviewer followed recommendations in Diamond, Luke and Uttal (2009) to avoid implied judgement or criticism and to make sure that participants feel comfortable to answer questions in an open and honest manner. Accordingly, the researcher tried to create a friendly, non-threatening atmosphere by offering participants to sit down during the interview, avoiding overly technical or academic terminology, and encouraging openness and honesty by pointing out that he was not affiliated with the museum and that the study was completely anonymous.

With regard to non-response bias, it is likely that people agreeing to take part in the interview are inherently more likely to share their views in museum environments than people who decline to participate. If this is the case, however, it can only lead to a more relevant sample considering the particular interview topic, as people who are more likely to share their views in a museum environment are plausibly more likely to have used commenting mechanisms and by extension to have an informed opinion about them. It could be argued therefore that any potential non-response bias in this particular study would only strengthen the survey results.

5.2.6 Ethical considerations

The researcher’s conduct during participant recruitment and interviews was guided broadly by the ethical consideration discussed in 3.5. The researcher only approached potential participants who seemed at least 18 years of age (despite the interview sheet showing an age range of 16-24) and the interview was completely anonymous. All participants confirmed their voluntary participation by signing a consent form. The survey instrument (see Appendix D) was cleared through the University of Brighton’s standard ethics approval process and approved by each of the participating organisations prior to commencement.

5.3 Findings

5.3.1 Demographics

The age distribution of the 104 interviewed visitors broadly corresponds to other largescale audience surveys (Figure 7a). For instance, the percentage of 35-44 (20%), 45-54 (19%) and 55-64 (15%) year olds is identical to the demographics reported for the Victoria & Albert Museum’s British Galleries (Creative Research, 2005). Standing out is the higher proportion of 16-24 (21%) than 25-34 (15%) year olds, which is typically reversed in other studies showing that fewer 16-24 year olds attend museums than 25-34 year olds (e.g. Creative Research, 2005; DCMS, 2012).
Chapter 5 Visitor perspective on commenting in museums

The sample included more female (56%) than male (44%) participants (Figure 7b). The difference is only slightly greater than the average of female (54%) and male (46%) visitors reported in Greenwood and Maynard's (2006) digest of a wide range of museum statistics.

80% of participants reported English as their first language (Figure 8a), with other first languages among interviewees including Dutch, French, German, Italian, Lithuanian, Spanish and Korean. The distribution is consistent with the relatively large numbers of overseas visitors reported in other studies (Creative Research, 2005).

76% of interviewees reported owning a smartphone (Figure 8b), which is higher than the UK national average of 51% (Ofcom, 2013) and 61% (Ofcom, 2014) around the time when the survey was carried out but in line with other contemporary large-scale visitor research (e.g. V&A, 2014).

Concerning the question "Do you have inside knowledge of museums or galleries?" many participants asked for clarification and were told that this would include having worked in or with a museum or gallery, or otherwise getting behind-the-scenes insights from someone they know. Interestingly, 23% of interviewees answered Yes to this question (Figure 8c), offering various explanations ranging from running a museum or gallery themselves, having worked or volunteered in a museum or gallery, having a partner working in a museum or gallery or being an artist dealing with galleries.
Regarding cultural interest and familiarity with museum environments, 66% of respondents visit museums once a month or more, another 24% visit more than twice a year and 10% visit once or twice a year (Figure 9a). Just over half of all interviewees report that they usually visit with friends and family with a further 21% visiting either with friends or on their own (Figure 9b), suggesting that most participants understand museum visits as a social occasion and have a suitable social environment for discussion and exchange during or after their visit. 28% of respondents usually visit on their own (Figure 9b), suggesting that a substantial minority sees museum visits as a personal, contemplative experience or as a professional interest.

5.3.2 Communication behaviour

The first question in this section, "Do you read labels for exhibits that interest you?" probes visitors' interest in curated information about exhibits and their willingness to engage with traditional object labels. 80% of respondents answered that they always or often read object labels and a further 17% said they sometimes read them. Only 3% report rarely reading object labels and none never reading them (Figure 10). In open answers, seven respondents made the point that they only read labels after looking at the exhibit in an effort to come up with their own interpretation first. This indicates a small but sizable minority who put a high value on personal interpretation of exhibits. While some of them also professed to have inside knowledge of museums and therefore might be biased (or just better informed), they are nonetheless part of the overall museum visitor demographic and their views are equally relevant.
A related question asked participants whether they tend to read and write visitor comments in museums if there is an opportunity to do so (Figure 11). Most interviewees answered "sometimes" (45% read, 45% write) to this question, considerably fewer answered "often" (18%, 13%) or "rarely" (17%, 29%) and even fewer answered "always" (4%, 3%) or "never" (15%, 11%). The data suggests that visitors are more likely to not engage than to engage for both reading and contributing comments. Notably, the gap in self-reported tendencies between reading and writing comments is only marginal and does not reflect the participation inequality (Nielsen, 2006) typically observed in online communities where 90% of users only read, 9% contribute intermittently and just 1% of users account for the bulk of contributions (see 2.3.3.3).

The next set of questions explored visitors’ verbal communication in museums by finding out to what degree they discuss the exhibition or exhibits with other people at different stages during and after their visit. Just over half of all participants report that they always (16%) or often (35%) talk with their friends or family while in the exhibition space, followed by people who sometimes (28%), rarely (11%) or never (9%) talk with their companions (Figure 12a), although most respondents in the "never" category also said that they usually visit on their own. Visitors’ communication gradually decreases, with the percentage of respondents who "often" talk with friends decreasing to 27% directly after the exhibition.
Chapter 5 Visitor perspective on commenting in museums

(e.g. in the museum’s cafe) and 10% later on (e.g. evening or following day) while the percentage of respondents who "sometimes" talk about the exhibition increases over the same time.

Most respondents answered that they never (57%) or rarely (29%) talk to strangers in the gallery, with only a minority reporting that they sometimes (17%) or often (1%) talk to strangers (Figure 12b). Open answers suggest that this is mainly due to social convention rather than a lack of interest in other people’s thoughts, as many people qualified their answer by saying that they would respond if addressed by someone, or that communication with strangers might happen as part of a guided tour.

This need for a context when communicating with strangers is also supported by answers to the follow-up question asking interviewees about their communication with museum staff (Figure 12c). While again the majority of respondents say they rarely (30%) or never (34%) talk to museum staff, the proportion of interviewees reporting talking sometimes (33%) or often (4%) to museum staff is approximately twice as high as the percentage of visitors talking to strangers. As museum staff represent the institution, there is a clear host/visitor relationship that justifies and provides context for someone approaching and talking to staff.

Visitors’ face-to-face communication does not correlate with their digital communication practices. Of the 79 interviewees who reported owning a smartphone, 84% say they never tweet, blog or otherwise talk online about an exhibition while in the exhibition space, and

![Figure 12: Participants’ communication with friends and family (a), other visitors (b) and museum staff (c)](image-url)
few say they do this sometimes (8%) or often (3%) (Figure 13). These numbers increase to 15% and 6% directly after the visit (e.g. in the museum cafe) and 25% and 11% later on (e.g. evening or next day), while the percentage of people who never communicate online decreases to 67% and 61% over the same time.

On the surface, these numbers are in stark contrast to a survey at the Victoria & Albert Museum (V&A, 2012), which found that 60% of visitors who brought a mobile device to the gallery used it to enhance their visit. However, the same study found a wide range of mobile phone uses, including taking images and looking up or sharing information. The percentage of people sharing their experience at the V&A via social media - 28% of visitors who brought a mobile device to the gallery (ibid) - is still higher than the numbers obtained in the present study, however, the difference is less pronounced, especially when looking at communication after the immediate gallery experience, e.g. when in the museum cafe.

Overall, key findings about visitors’ communication in museums include:

- most visitors have a strong interest in curated information, although there is a vocal minority who prioritise the personal interpretation of exhibits
- visitors are familiar with the concept of an object label as an established source of curated information
- many visitors talk with friends and family about exhibits while in the gallery space and afterwards, with communication becoming more sporadic later on
- communication with other visitors is rare due to social protocol and a lack of context in which such communication can happen
- only few visitors communicate online about the exhibition while in the gallery space, although this doubles immediately afterwards and further increases later on

Together, the results suggest that SOLs should aim to complement rather than compete with visitors’ current communication behaviours. Where visitors currently focus mainly on consuming curated information, SOLs can provide an opportunity to create and share their own interpretations, and where visitors communicate verbally with friends or family, SOLs can provide a platform to communicate digitally and asynchronously with other visitors.
they don't know and with museum staff. While this lack of overlap poses challenges with regard to the acceptance of SOLs, it also offers opportunities to extend visitors’ communication.

### 5.3.3 Commenting mechanisms

The next part of the interview probed visitors' familiarity with, and preferences for, various commenting mechanisms. Participants were first shown images of six common feedback mechanisms and then asked which ones they had seen before, which ones they had used before and which ones they prefer. Participants were also asked to explain what they liked about their preferred mechanisms or disliked about others.

![Figure 14: Participants' awareness, use and preferences of common commenting mechanisms](image)

Quantitative data indicating participants' awareness, previous use and preferences was simply aggregated (Figure 14), while more complex open answers explaining the reasons behind participant's preferences were qualitatively analysed using an emergent coding scheme described in Miles and Huberman (1994). Answers relating to specific commenting mechanism are summarised below.

**Visitor Books** are the best-known (98%), most-used (72%) and overall favourite (54%) commenting mechanism among interviewees. When asked what they liked or disliked about visitor books, interviewees offered a wide range of aspects:

- Some think of visitor books as a traditional medium they like and are familiar with.
- Some think a physical book is more human, authentic, personal, valuable and permanent and also provides privacy and anonymity.
- Many respondents had a particular interest in seeing other people's handwriting, which made the experience more personal for them.
- Some like the physicality of visitor books and the related accessibility and easy handling, as they can just leaf through pages and quickly jot down a comment.
- Some like the freedom when writing by hand, pointing out that it is less prescriptive, less like a form, and enables them to add drawings if they like.
- Some like reading other people's comments.
Some think a comment book at the end of an exhibition lacks relevance and can be difficult to find, suggesting they would prefer to comment right at the exhibit. Some find comment books dated and boring.

*Comment Cards* are the second-best-known (76%) commenting mechanism, however, only 38% of interviewees have ever used them and only 18% prefer them over other mechanisms. When asked why they like or dislike comment cards, visitors offered a range of answers:

- Some associate comment cards with a specific purpose such as asking a question or lodging a complaint.
- Some think comment cards are more personal and are taken more seriously.
- Some like that they can see other people’s handwriting when comment cards are being displayed.
- Some like the physicality and immediacy of comment cards, pointing out that they can just write something without the need for computers.
- Some like the freedom and versatility of comment cards, pointing out that it is less prescriptive and allows for drawings.

*Feedback boards* are less well-known (55%) but much liked (31%) and consequently almost as much used (35%) as comment cards despite being less frequently deployed in museums. Specific aspects visitors like and dislike include:

- Some like reading other people’s comments.
- Some like to see other visitor’s handwriting, and value the option to not only write text but also be able to scribble and add drawings on feedback boards.
- Some like the physicality and accessibility of feedback boards, which they find easy to read and overall less demanding than other feedback mechanisms.
- Some like the immediacy of feedback boards that enable them to comment on an exhibit straight away (as opposed to a comment book at the end of an exhibition).
- Some associate certain qualities with feedback boards, seeing them as original, fun, informal, interactive, interesting and personal. However, some take a more critical stance saying they seem contrived for adults and are more appropriate for children.
- Some point out that feedback boards "feel like you create something" and that comments are more likely to be taken on board. They think putting up a feedback board shows a genuine interest in visitors’ views on the museums part.
- Some aspects of feedback boards are controversial, with people referring to them as positive or negative qualities, e.g. some say they like post-it notes while others say they remind them of the office, and some like to have an overview of all comments while others think it hinders original thought and makes people try to fit in.
Feedback screens are least known (38%) among the discussed commenting mechanisms, however, they are (together with museum websites) the only mechanism where the number of people who say they prefer (18%) them is higher than the number of people who report actually having used them (17%). Aspects visitors liked and disliked include:

- Some like that they are interactive, dynamic and offer context information.
- Some find feedback screens easy to use, fool proof and not overpowering.
- Some like the immediacy of feedback screens enabling them to comment on an exhibit straight away (as opposed to a comment book at the end of an exhibition).
- Some see feedback screens as modern, useful, precise, concise and confidential (as opposed to online mechanisms that link to one's social profile).
- Negative aspects mentioned include that feedback screens usually ask a question instead of letting the visitor choose their own topic, and that they "take too long" when guiding users through several screens.

Museum websites are well known among visitors as a commenting platform (63%). Similar to feedback screens, the number of people who prefer website comments (19%) is higher than the number of people who have actually used them (17%). Likes and dislikes include:

- Some like the accessibility of commenting on a website, pointing out that they can conveniently comment in their own time without the need to be present at the museum and that it enables them to read comments before their visit.
- Some point out inherent strengths of online commenting such as interactivity, reach and usability aspects, including being able to scroll and read whole conversations.
- Some point out that comments are more likely to be read by curators and taken seriously when online due to their publicity.
- Negative aspects mentioned include that online comments are a "free for all" inviting trolling and that they are something for geeks.

Social networks as a platform for feedback and commenting are as well-known as museum websites (63%) but more interviewees have used them (25%) and more prefer them (20%). Specific aspects interviewees liked and disliked include:

- Some like the accessibility of social network comments as they can conveniently read and write comments in their own time and from outside the museum.
- Some point out inherent strengths of social media including open discourse, e.g. being able to broadcast comments and discuss aspect, and the integration with one’s communication habits, e.g. when tagging images or linking content to other activities.
- Many respondents point out the ease of use of social media enabling them to comment and share with minimal effort.
Negative aspects mentioned include limitations on the lengths of comments (referring to Twitter's 140 character limit) and that it is something for geeks.

The results describe the reasons why visitors like specific commenting systems and show many overlaps in the underlying aspects of these preferences. In order to identify these more abstract qualities, a second step in the qualitative data analysis involved analysing and synthesising visitors' preferences across all commenting systems. Findings from this process (Findings from Visitor survey [FVn]) and how they can inform the design of SOLs are discussed in the following paragraphs:

Ease of use, accessibility and immediacy are the most cited qualities participants liked about commenting mechanisms. Visitors want to be able to comment with minimal effort both on the spot and from home in their own time.

**FV1:** The interaction with SOLs should be as easy and direct as possible, removing any barriers that delay users or require additional cognitive resources when submitting a comment.

**FV2:** SOLs should support both in-situ commenting while at the exhibit and remote commenting after the encounter when users had time to reflect.

Another important aspect relates to freedom of expression in terms of choosing a topic to comment on, not being hemmed in by prescriptive form fields that ask for extra information and using both text and drawings.

**FV3:** SOLs should give users as much freedom as possible when submitting comments, e.g. not prescribe a specific topic or format and not force them to enter extra information.

An underlying message in many answers and across different commenting mechanisms is that interviewees want their comments to be read and taken seriously by the institution.

**FV4:** SOLs should provide information on how the organisation deals with submitted comments.

Several participants mentioned qualities inherently associated with digital connected media such as being modern and interactive, affording open discourse, sharing and broadcasting, and integrating with personal communication habits.

**FV5:** SOLs should enable visitors to read and reply to each other's comments.
Some participants mentioned privacy, anonymity and confidentiality as positive factors for commenting systems. While usually attributed to analogue systems, this was also mentioned for digital systems that do not automatically link to one's online profile.

Other qualities emerging from the analysis of visitors' preferences include the ability to read other people's comments and see their handwriting, as well as the use of a familiar, physical medium they can touch and leaf through and write on with a pen, which often is perceived as making commenting a more human, authentic and personal experience.

While the ability to read other people's comments is covered in [FV5], several of these qualities are associated with analogue media and are difficult to match with digital systems. For instance, the experience of writing with a stylus on an interactive screen does not match the haptic qualities of writing with a pen on paper (Cho et al., 2016) and swiping paged content, even if enhanced with skeuomorphic page-turn animations, does not match the physicality of leafing through actual pages in a physical book.

Given that these qualities cannot be effectively reproduced in digital systems based on current technologies and that trying to imitate them regardless would limit the interaction design of SOLs by grounding it in the user experience of physical counterparts such as visitor books or comment cards, they are not included in the design recommendations at this stage but might be reconsidered in future research when suitable technologies are available (see 10.4 Open issues and future work).

### 5.3.4 Metadata for comments

The next section in the interview explored what kind of information about authors visitors are interested in when reading comments, as default fields in many other systems such as name or username might not actually meet visitors' preferences. A related question looks at the flipside of showing such information by asking participants what kind of information about them they would be happy to supply when submitting a comment. Answers to this second question also give an insight into participants' attitudes towards privacy.

The results suggest that many visitors are interested in many different kinds of information about comment authors (Figure 15), with open comments suggesting that people are interested mostly in information that helps them to contextualise and better understand
the comment. With regard to actual data fields, only the author’s age is of interest to more than half of all participants (55%), other aspects are only of interest to minorities. A large proportion of respondents (39%) report not being interested in any additional information at all. A common argument in this line was that additional information about the author only brings into play prejudice and stereotypes that detract from the actual comment at hand.

Interestingly, participants’ answers suggest that they are more willing to provide information about themselves than they are interested in reading. While at first sight this is surprising, open answers offer interesting insights how participants deal with privacy issues when providing information about themselves, e.g. several participants mentioned they would give a wrong name to conceal their identity or a wrong age if they thought someone next to them might see it. A substantial percentage of respondents (27%) say they would not provide any information about themselves. Reasons include privacy concerns, usability concerns and concerns that author information detracts from the actual comment (see above).

While age stands out from other author information in that more than half of respondents are interested in it when reading comments and would be comfortable to provide it when submitting comments, there also is a large percentage of participants who are not interested in it or would not provide it. On balance, the only valid finding supported by these results is that any additional information about authors should be optional when submitting or displaying comments (see FV3 above).

5.3.5 Readership of comments

This section of the interview enquires about participants’ views on who should read their comments and their assumptions about who actually reads them. It explores motivational barriers to active participation by contrasting the desired readership of comments with the presumed readership.
Answers suggest that an overwhelming majority of participants think that comments and feedback submitted to a museum or gallery should be read by staff (Figure 16a), ranging from directors (33%) and senior staff (79%) to junior staff (46%) and a dedicated panel or team dealing with comments (12%). In addition, many participants think comments should be read by artists (28%) and other visitors (26%).

Some visitors picked up on the ambiguity in this question and pointed out that the intended target audience depends on the kind of comment, however, there seemed no agreement on who should read which type of comment, e.g. answers included curators, artist and other visitors for interpretation type comments and curators, "logistics", senior staff and director for feedback type comments.

Many participants who answered that comments should be read by senior staff argued that only they can make a difference and ensure that the comment can have an impact on the exhibition or the museum as a whole. Acknowledging that senior staff might be too busy to read all comments, several interviewees suggested that junior staff could sift through comments and pass important or interesting ones on to senior staff.

A large number of interviewees proposed that comments should be read by as broad an audience as possible, suggesting "all levels at the museum", "everybody" and "anyone" as target audiences. Two interviewees mentioned funders as a target audience, reflecting the high percentage of respondents who reported having inside knowledge of museums (22%).

Figure 16: Participants' views on who should read submitted comments (a) and assumptions whether that is actually the case (b)
When asked in a follow-up question whether they think that comments are actually read by the intended target audience (Figure 16b), participants gave mixed responses. Only 12% were positive and a further 13% hopeful, with answers ranging from "suppose so" and "hope so" to "would like to think so" and "sometimes". Many participants were unsure (9%), thought it unlikely (17%) or simply assumed this was not the case (18%), while others gave conditional answers (11%) or no answer at all (20%). Some participants answered that it depends on the organisation and staff, suggesting that comments were only read in smaller organisations and by more effective, hands-on staff. Several interviewees expressed sarcastic views when answering this question, indicating a presumed disregard for visitor comments by museums (e.g. "They probably just bin them straight away").

Overall, participants' answers suggest that at best there is considerable uncertainty among visitors whether comment are actually read by the people they are intended for. As from a visitor perspective this undermines the whole purpose and utility of commenting, it is a critical aspect to address. One way to do this would be museum staff actually replying to comments (at least to some) and visibly getting involved on the commenting platform. A precedence for this type of responsive visitor engagement has been set by the recent ASK project at Brooklyn Museum (Bernstein, 2015), where visitors can ask questions via a mobile application and get answers from staff in real-time. However, as this requires staff time and thereby impacts on budgets, a balance must be found between complete facilitation and lightweight responsiveness.

While from a museum perspective this means primarily putting a suitable policy and process in place and identifying responsibilities, from a technical design perspective it means that readers must be able to identify staff comments on the system.

| FV9: SOLs should provide information about who is going to read submitted comments. |
| FV10: SOLs should provide functionality for museum staff to post and reply to comments without being present at the exhibit. |
| FV11: SOLs should mark staff comments so that they are easy to identify by visitors. |

### 5.3.6 Moderation of comments

This section of the interview probes participants' views on comment moderation and censorship in museums, which plays into their perception of transparency and accountability of institutional processes and thereby impact on their motivation to use and contribute to commenting systems.
Most interviewees (78%) assume that museums sometimes suppress or remove comments and feedback (Figure 17a). With regard to moderation criteria, 73% of participants thought museums would take down offensive comments and 63% thought that was justified, while 45% offered other criteria that 32% were supportive of (Figure 17b, c). While only few respondents expect drastic unjustified censorship by institutions, many participants suspect a bias towards making the institution look good. 38% of interviewees think that museums suppress or remove comments that reflect negatively on them but only 11% approve of this (Figure 17b).

FV12: SOLs should provide functionality for content moderation.

Open comments suggest that while there is a sizeable minority who do not tolerate any kind of moderation in the interest of freedom of expression, arguing that an open debate must be able to cope even with offensive comments, the majority of interviewees are pragmatic about this aspect, suggesting that museums have a legal duty to take down some kinds of comments and that museums are entitled to take down offensive comments that might spoil the experience for other visitors. Some interviewees suggest that museums should actively curate comments to project a positive image that might help to attract more visitors and prop up their finances.
Most interviewees assume that museums take moderation seriously and that it involves directors (7%), senior staff (40%), junior staff (45%) or a dedicated panel or team (5%) (Figure 18). A sizeable minority, however, has more cynical views, suggesting it might be marketing people in the museum (10%) or an intern or volunteer (8%). Open comments show that many visitors are aware that comment moderation is additional work for museums, with some suggesting that junior staff or volunteers might sift through comments in a first step and then pass on critical ones to senior staff to make a decision.

FV13: SOLs should separate content monitoring from content moderation.

5.3.7 Conservation of comments

This section of the interview probes participants' views on the conservation of comments. The first part focuses on how long comments should be kept by museums and how long they think museums actually keep comments. As this aspect may be perceived by visitors to reflect the value an institution puts on submitted comments, it can play into their motivations to engage with a commenting system (e.g. low expectations of attributed value might be a reason for non-engagement). Conservation also plays into privacy and data protection issues that might influence visitors' willingness to contribute comments, particularly if they contain additional author information.

The results show that participants' views on how long comments should be kept are in most cases quite close to their assumptions on how long they are actually kept. One exception to this concerns the conservation of visitor books, which 55% of interviewees would like to be kept indefinitely and 15% for a certain period, while only 26% assume they are actually kept indefinitely and 46% assume they are kept only for a certain period.
Chapter 5 Visitor perspective on commenting in museums

Open comments suggest that practical aspects are the main reason for this discrepancy with many interviewees saying that while visitor books are a valuable record that should be kept forever it would be difficult and costly to indefinitely store an ever increasing number of them. Similar arguments, although less often, were made for comments in loose paper format which most participants judged as difficult to store. Together, the results suggest that visitors recognise the value of comments, especially over time, but are aware of the cost and effort involved in conservation and assume museum’s practices to be broadly in line with these considerations.

The second part focuses on conservation practices that involve the remediation or transfer of comments between different systems. In particular, participants were asked whether they assumed museums to employ these practices or not, which might in turn influence their motivations to contribute comments.

Regarding the digitisation of comments in physical formats (Figure 20a), visitors’ assumptions are distributed over the whole range from Yes to No, however, most (37%) assumed that museums probably do not digitise physical comments, mainly due to the effort and costs involved. At the same time, many interviewees thought museums should digitise comments made in physical formats as this would make them easier to research and enable the public to browse them on digital displays. Some visitors suggested books should be digitised but not comments on loose paper, or that only some comments should be digitised, e.g. if they relate to a special project or exhibition.
Regarding the harvesting and storage of comments made on social networks (Figure 20a), participant's assumptions are distributed between Yes (14%), Probably (21%), Maybe (6%), Probably Not (24%) and No (17%) with others (13%) saying they do not know or not providing an answer. Many participants mentioned resource constraints as the main point against harvesting, assuming it would be difficult to do technically, or legal issues as it possibly would violate the social network’s copyright, while others suggested that museums should harvest social network comments, pointing out that storage is cheap and that it would be easy to do. Some interviewees offered that only some comments should be harvested, e.g. if they are significant or part of a trend.

Together, the results suggest that there is a wide range of assumptions and opinions among visitors about the remediation, harvesting and conservation of comments. While many interviewees said they had never thought of these aspects, others had definite assumptions and opinions that might play into their motivations to contribute. Clarifying these aspects would enable all visitors to make more informed decisions about their engagement with commenting platforms.

FV14: SOLs should inform users about the institution's policies with regard to the remediation, harvesting and conservation of comments.

5.3.8 Ownership and reuse

This section explores visitors' views on ownership of comments submitted to a museum. Pilot interviews had shown that participants struggle initially when confronted with abstract questions about content ownership and appreciate concrete examples. Consequently, the researcher began this section with a series of scenarios exploring how museums might possibly use comments and then asked participants for each of them whether they thought such use was justified. The scenarios touched in particular on the remediation and re-contextualisation of comments, which visitors might not think of at the point of submission.
The results (Figure 21) show that a considerable percentage of respondents think that museums can do almost anything they like with submitted comments. A key argument mentioned in this line was that visitors should know that when they submit a comment in a public forum (such as a museum) they automatically waive all rights and lose control over it. Some also pointed out that they would like the idea of their contribution acquiring some fame when published by the museum.

![Figure 21](image)

*Figure 21: Participants views on the acceptability of a range of possible uses of submitted comments*

Most participants felt that the described uses were only permissible if the comment was anonymous so that the author could not be identified. Even more restrictive, a sizeable minority of respondents answered that such uses were only acceptable if the visitor had given prior consent to do so. While for some this was covered by the museum displaying a notice with terms of use and visitors implicitly agreeing to this when submitting a comment, others called for explicit informed consent obtained by the museum for a specific use. Along similar lines, some participants suggest a staggered system where basic anonymous uses of comments are fine, consent is required if a comment includes a name or if it is used out of context and express permission (in addition to consent) is required for commercial uses.

Some participants argued that any uses at all beyond the context in which a comment was made, i.e. in a specific location at a specific time and using a specific medium, would be outside the commenter’s original intent and therefore not acceptable.

 Declining approval rates for the different scenarios reflect their increasing radicality, with fewer participants supporting unrestricted use, even if anonymous, and more participants requiring informed consent or answering they are not acceptable at all. Commercial use of comments clearly stands out, with 45% of interviewees saying it is not acceptable at all and a further 22% saying it requires informed consent. However, even with commercial uses 13% have no objections at all and a further 17% would only require the comment to be anonymised.
In many cases, the discussion of specific scenarios led naturally to the next question in this section asking participants whether there should be a notice at the point of submission explaining how comments might be used by museums (Figure 22a). The overwhelming majority answered Yes to this question (84%), with some suggesting it should not be too detailed and others suggesting it should provide concrete examples. Among the participants who answered that there should not be a notice (16%), the main arguments were that it is not necessary, that people know anyway, that nobody would read it and that commenting "should be enjoyable, not an explicit contract".

FV15: Visitors should be notified how comments might be used by the museum.

FV16: SOLs should provide terms of use in an unobtrusive way.

A follow-up question explored the potential pitfalls of displaying such a notice, as it might raise negative associations and turn commenting into something problematic. When asked whether a notice would "put them off" contributing a comment (Figure 22b), most participants answered No (60%). While some of these were unconditional, emphasising that the openness and clarity a notice provides would instead encourage them to contribute, many others qualified their answer by adding that while the notice itself would not deter them they might not agree with the terms set out in the notice and not contribute on these grounds, or that while a notice would not deter them personally it might well deter others. Among the participants answering Yes (11%) or Probably (13%) to this question, common arguments were that a notice would make them more cautious or that it would ruin the experience of acting in the moment.

The final two questions in this section further explored content ownership and use, first by asking participants whether they think they should have a right to request removal if their
comment was used in the ways described above, and then by asking them who should own submitted comments and who they think actually owns them.

With regard to the former (Figure 23a), 53% of participants think that visitors should have an unconditional right to request removal. A further 28% think visitors should be able to ask for removal if certain conditions are met, mainly if the comment includes their name or if they had not previously agreed to any terms of use. However, a sizeable minority of 19% think that visitors should not have a right to request removal at all. Key arguments in this line were that visitors should know that they lose control when submitting a comment in a museum and that it might be difficult to prove authorship of comments when requesting removal.

Regarding the direct question about content ownership, participants' answers suggest a marked difference in their views between moral ownership and assumed legal ownership (Figure 23b). While only 31% of respondents think that submitted comments should be owned by the museum, 62% think that the museum has actual ownership. Even more pronounced, 23% of respondents think that ownership of content should be shared between the museum and the contributor, but only 2% think that ownership is actually shared.

These differences suggest that many visitors see ownership of content unjustly skewed towards the museum. Interviewees often hint at a perceived power differential between individual and organisation, especially when content is submitted through a medium that is owned or controlled by the organisation. Many respondents argue that because the medium is owned by the museum, it automatically owns the content contributed via that medium. While some participants point out that ownership of the intellectual property rights to the comment lies with the visitor in accordance with copyright laws, they also concede that in practice this might be difficult to assert.

In order to avoid uncertainty about content ownership preventing visitors from contributing comments, institutions should shape their intellectual property policies for...
user-generated content in accordance with visitors' wishes and communicate them in clear, plain term that are easy to understand. At the same time, museums should address the common perception that comments are owned and controlled by the museum because it owns the medium through which they are submitted. One way to do this is by providing functionality that gives visitors control over their comments even after they are submitted.

FV17: It should be clear to visitors who owns the intellectual property rights to comments submitted to SOLs.

FV18: SOLs should provide functionality enabling users to take control of their submitted comments.

Stepping back from intellectual property rights and concrete use cases, many participants appealed to common sense and argued that comments are made in a certain context and should be used with "decency" and "honesty". Regardless of actual content ownership, they refer to "fair use" and think visitors should have a say in how their comments are used by the museum, not least because the museum wants them to come back.

5.4 Discussion

Communication during and after visits

The survey confirms traditional object labels as a well-established (though uni-directional) communication channel, with the vast majority of visitors saying they read them always or often, while engagement with visitor commenting platforms is less common for both reading and writing comments. Most visitors talk with friends and family during and after their visit, however, only very few communicate through online channels on their mobile phone, especially when in the exhibition space, indicating that visitors' current in-gallery behaviour provides little foothold for SOLs, which depend on visitor's mobile device to add comments.

Commenting mechanisms

Traditional visitor books are best known, most used and overall favourites among visitors, followed by comment cards and feedback boards. Feedback screens were least well known and used, however, in proportion to usage they are better liked than any non-digital mechanism. This also holds for museums’ websites and social media platforms, however, engagement for both of these is comparatively low compared to visitors’ high awareness of them. Based on an analysis and synthesis of reasons visitors gave for their preferences for specific commenting platforms, a series of requirements for SOLs have been identified relating to ease of use, privacy, freedom of expression and interaction, and integration with visitors' communication behaviours.
Comment metadata

Visitors’ interest in additional information attached to comments, such as the author’s age, gender, name, etc. is very diverse, ranging from an interest in any and all such information to no interest at all. Surprisingly, the percentage of people prepared to provide such information is higher than the percentage of people interested in reading it. While a key argument for such information was that it supports the interpretation of comments, many visitors pointed out that it also brings into play prejudice and stereotypes that might distract from the message and hinder interpretation. Overall, the findings suggest that such additional data is not strictly necessary and should be optional when submitting and displaying comments.

Intended audience

Intended target audiences for comments vary. Depending on the type of comment, they include curators, artists and other visitors for interpretation comments and directors and senior staff who "can make a difference" for feedback comments. However, only a quarter of visitors believe that comments are actually read by the intended target audience while many visitors find this unlikely and some hold distinctly cynical views on this aspect. Overall there is considerable uncertainty among visitors as to who actually reads their comments, leading to a range of requirements for SOLs to make this aspect more transparent.

Moderation

Most visitors assume that museums sometimes suppress or remove comments, and the majority of them thinks this is justified for offensive content. Only few visitors expect the moderation to be grossly unfair, however, many assume that there is probably an unjustified bias towards making the museum look good. Visitors' assumptions as to who in the museum makes decisions about content moderation are varied, however, many suggest pragmatic approaches where junior staff do most of the work but leave critical decisions to senior staff. Overall the findings confirmed the need for content moderation on SOLs and informed the requirement to separate content monitoring from content moderation.

Conservation

With regard to conservation, one half of visitors thinks that comments should be kept indefinitely while the other half thinks that comments should be kept until the end of the exhibition, or only for a certain period of time or not at all. Often these latter views were justified with privacy concerns or with assumed costs for conservation. Visitors' views on digitising physical comments and harvesting social media comments suggest that there is considerable uncertainty about these aspects. As this might play into their motivations to contribute, it indicates a requirement for SOLs to provide information about the host organisation's policies on remediation, harvesting and conservation of comments.
Ownership

Closely related to conservation, IP ownership and reuse of comments is a complex and largely unclear subject to most visitors. Reflecting this complexity, visitors express differentiated views under what circumstances and conditions museums are entitled to reuse comments, with anonymity and informed consent emerging as key aspects. The majority of visitors would like these aspects to be clarified at the point of submission, however, a substantial minority thinks this is not needed and would unnecessarily formalise the process of commenting. Even among proponents of displaying terms of use many admit that such a notice might put them off commenting or at least make them more careful. Many visitors see ownership of content unjustly skewed towards the museum as they believe that ownership of the medium through which comments are made also implies ownership of the IP or otherwise that it would be difficult for visitors to assert their copyright. Reflecting this perceived power differential, half of all visitors would like to have an unconditional right to request removal and a further third would advocate a conditional right, usually depending on whether the visitor previously accepted the terms of use. SOL requirements derived from these findings include the need to inform visitors about IP issues and the need for functionality that gives visitors control over their comments after submission.

5.5 Limitations

With regard to validity, the survey is based on a large sample with similar demographics to other large-scale audience research in the cultural heritage sector concerning age and gender distribution, mobile phone ownership, frequency of museum visits and percentage of people whose first language is not English. While the study used convenience sampling rather than probability sampling, several measures were taken to reduce bias and widen the range of audiences from which participants were drawn.

A weakness of the study is that interviewees’ answers were recorded in interview notes rather than being audio recorded and verbatim transcribed, with the former not feasible in a gallery environment and the latter not feasible due to the large number of interviews. To mitigate this, several measures were taken to ensure that notes correctly reflected participants answers, including the use of a custom coding sheet based on answers from pilot interviews to speed up note-taking, and the practice of reviewing notes immediately after each interview while the memory of participants’ responses was still fresh.

With regard to transferability, the survey provides valuable insights into visitors’ preferences, expectations and mental models of commenting in museums that go far beyond informing the requirements analysis for SOLs. The findings will be of interest to the wider cultural heritage sector, where they can inform policies for collecting, handling, conserving and reusing visitor-generated content.
5.6 Conclusions

This chapter provides answers to research question RQ2, asking how SOLs can support commenting in museums. While the literature focuses primarily on the organisation's perspective when discussing user-generated content in museums, the research explores this question from a visitor perspective by surveying museum visitors' preferences and expectations for commenting and translating these into requirements for SOLs.

The survey involved 104 structured visitor interviews carried out at three locations, ranging from small local art gallery to medium-sized mixed museum and large international art museum. Interview topics included visitors' communication habits during and after visits, preferences for particular commenting mechanisms, attitudes to additional information submitted with comments, presumed readership, moderation and conservation of comments as well as aspects around ownership and potential reuse of comments.

The discussion summarises and interprets findings for each of these topics, providing a structured overview of visitors' preferences and expectations of commenting in museums. Findings from the survey resulted in requirements for SOLs, which are marked in the context from which they arise to aid comprehension.

In addition to informing the design of SOLs, the main contribution of this chapter is to provide for the first time a visitor perspective on commenting and feedback in museums. Based on a large and diverse sample, the findings offer valuable insights that hopefully will be of use to the wider cultural heritage sector with regard to informing policies and platforms for user-generated content.
6 User and scenario modelling

6.1 Introduction

This chapter identifies potential target users of SOLs and looks at existing audience research in museums with a view to constructing a set of personas representing archetypical users. It then develops a series of scenarios in which these personas encounter and interact with SOLs in various ways, in order to inform the requirements analysis and identify problems with design choices.

6.2 Target users

Courage and Baxter (2005) distinguish between primary users, who use a product directly, secondary users, who use it through an intermediary, and tertiary users, who are otherwise affected by it. While a requirements analysis does not necessarily need to include secondary and tertiary users, they should be specified and kept in mind during scenario development as they might indirectly affect acceptance and use of the product (ibid).

With regard to visitors, the primary users of SOLs are people who actually interact with them to browse annotations or add their own commentary or ratings. Secondary users in Courage and Baxter's (2005) sense are visitors who notice and react to SOLs without directly interacting with them. This might include visitors who use them indirectly through a primary user as an intermediary, for instance reading the device screen over the primary user's shoulder or co-authoring comments submitted by the primary user. Tertiary users include people who might notice SOLs and are affected by other visitors using the system, for instance someone reaching over to interact with a SOL.

With regard to museum professionals, primary users include gallery managers who install, configure and maintain SOLs in the gallery space and staff who monitor engagement and moderate user-generated content on SOLs. Secondary users include visitor-facing staff and volunteers who might be approached by visitors with questions about the use and purpose of SOLs. Tertiary users include senior staff looking to integrate SOLs with the organisation's digital strategy and educational goals.

Both of these user groups represent important stakeholders in the overall system design and are consulted in the requirements analysis and evaluation of the developed system.

6.3 Audience research

The primary means for museums to learn about their audience are audience research and visitor research. A useful distinction between audience and visitor is provided by Forrest (2011), who suggests that "audience" is a bigger population than "visitors" as it includes both actual and potential visitors. For the sake of simplicity, both visitor and audience research shall be referred to as "audience research" in this chapter.
A key aspect in audience research is to classify (actual and potential) visitors along useful characteristics that can inform museums' efforts to expand their reach and improve the visitor experience. While traditional audience research typically aims at segmenting and quantifying visitors into socio-economic groups, more recent approaches focus on identity, lifestyles and aspirations in order to identify drivers and barriers to participation. The following paragraphs discuss a range of classification systems used in various audience research reports.

**a) British National Readership Survey**

The NRS social grades are a well-established system of demographic classification in the UK and are frequently referenced in audience research (e.g. Creative Research, 2005; Fresh Minds 2007; Mc Nabola, 2008). Originally developed in the 1960s by the National Readership Survey (NRS) to classify readers, the system has become a standard for market research across a wide range of domains (Collis, 2009). NRS social grade definitions, now maintained by the Market Research Society (MRS, 2006), and their respective percentages of the UK population, are listed in Table 18.

<table>
<thead>
<tr>
<th>Percentage of UK population</th>
<th>Social Grade</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>4%</td>
<td>A</td>
<td>High managerial, administrative or professional</td>
</tr>
<tr>
<td>23%</td>
<td>B</td>
<td>Intermediate managerial, administrative or professional</td>
</tr>
<tr>
<td>29%</td>
<td>C1</td>
<td>Supervisory, clerical, junior managerial, administrative or professional</td>
</tr>
<tr>
<td>21%</td>
<td>C2</td>
<td>Skilled manual workers</td>
</tr>
<tr>
<td>15%</td>
<td>D</td>
<td>Semi and unskilled manual workers</td>
</tr>
<tr>
<td>8%</td>
<td>E</td>
<td>State pensioners, benefits, casual or lowest grade workers, unemployed</td>
</tr>
</tbody>
</table>

*Table 18: NRS social grades. Source MRS (2006).*

**b) National Statistics Socio-Economic Classification (NS-SEC)**

The NS-SEC is the primary social classification system in the UK and has been used in all official statistics and surveys in the UK since 2001 (ONS, 2010), including the long-running quarterly Taking Part survey of cultural participation carried out by the Department for Culture, Media and Sport (e.g. DCMS, 2012). Unlike social grades in the NRS, social classes defined in NS-SEC apply to individuals rather than households and are based on professional status and qualifications rather than purchasing power (Collis, 2009). While the full version of NS-SEC has 17 categories, research reports usually reference the abbreviated version with 8 categories. Table 19 lists the short form of NS-SEC social class definitions together with their percentages of the population in England and Wales.
### Table 19: NS-SEC social classes. Source ONS (2011).

<table>
<thead>
<tr>
<th>Percentage of England and Wales population</th>
<th>Social Class</th>
</tr>
</thead>
<tbody>
<tr>
<td>20.6%</td>
<td>Higher managerial and professional occupations</td>
</tr>
<tr>
<td>20.8%</td>
<td>Lower managerial and professional occupations</td>
</tr>
<tr>
<td>12.7%</td>
<td>Intermediate occupations (clerical, sales, service)</td>
</tr>
<tr>
<td>9.4%</td>
<td>Small employers and own account workers</td>
</tr>
<tr>
<td>6.9%</td>
<td>Lower supervisory and technical occupations</td>
</tr>
<tr>
<td>14.1%</td>
<td>Semi-routine occupations</td>
</tr>
<tr>
<td>11.1%</td>
<td>Routine occupations</td>
</tr>
<tr>
<td>11.2%</td>
<td>Never worked and long-term unemployed</td>
</tr>
</tbody>
</table>

#### c) BBC Labs Great British Class Survey

The Great British Class Survey commissioned by the British Broadcasting Corporation (BBC) in 2011 is the largest study of class in the UK to date (Savage et al., 2013). While class in the UK has traditionally been defined by occupation, wealth and education, the BBC survey is based on economic, social and cultural dimensions, measuring economic capital (income, savings, house value), social capital (the number and status of people someone knows) and cultural capital (the extent and nature of cultural interests and activities). The survey resulted in the definition of seven new classes for the UK. Classes and their percentage of the UK population are listed in Table 20.

<table>
<thead>
<tr>
<th>Percentage of UK population</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>6%</td>
<td>Elite - the most privileged group in the UK, distinct from the other six classes through its wealth. This group has the highest levels of all three capitals.</td>
</tr>
<tr>
<td>25%</td>
<td>Established middle class - the second wealthiest, scoring highly on all three capitals. The largest and most gregarious group, scoring second highest for cultural capital.</td>
</tr>
<tr>
<td>6%</td>
<td>Technical middle class - a small, distinctive new class group which is prosperous but scores low for social and cultural capital. Distinguished by its social isolation and cultural apathy.</td>
</tr>
<tr>
<td>15%</td>
<td>New affluent workers - a young class group which is socially and culturally active, with middling levels of economic capital.</td>
</tr>
<tr>
<td>14%</td>
<td>Traditional working class - scores low on all forms of capital, but is not completely deprived. Its members have reasonably high house values, explained by this group having the oldest average age at 66.</td>
</tr>
<tr>
<td>19%</td>
<td>Emergent service workers - a new, young, urban group which is relatively poor but has high social and cultural capital.</td>
</tr>
<tr>
<td>15%</td>
<td>Precariat - or precarious proletariat - the poorest, most deprived class, scoring low for social and cultural capital.</td>
</tr>
</tbody>
</table>

*Table 20: New social classes in the Great British Class Survey. Source Savage et al. (2013).*
d) A Classification Of Residential Neighbourhoods (ACORN)

ACORN (CACI, 2010a) is a geo-demographic segmentation of the UK’s population, categorising postcodes and consumer households into 5 categories, 17 groups and 56 types. Referenced in the DCMS (2012) Taking Part survey, it provides detailed consumer profiles and measures key indicators for households against the national average. The widely referenced 2005 version (CACI, 2005) of ACORN has been updated with new categories, groups and types in 2010 (CACI, 2010a). An overview of categories in both versions, together with percentages of UK population, is given in Table 21.

<table>
<thead>
<tr>
<th>ACORN 2005 categories</th>
<th>UK Population</th>
<th>ACORN 2010 categories</th>
<th>% of UK Population</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wealthy Achievers</td>
<td>25.1%</td>
<td>Affluent Achievers</td>
<td>22.2%</td>
</tr>
<tr>
<td>Urban prosperity</td>
<td>10.7%</td>
<td>Rising Prosperity</td>
<td>8.6%</td>
</tr>
<tr>
<td>Comfortably off</td>
<td>26.6%</td>
<td>Comfortable Communities</td>
<td>27.3%</td>
</tr>
<tr>
<td>Modest means</td>
<td>14.5%</td>
<td>Financially Stretched</td>
<td>24%</td>
</tr>
<tr>
<td>Hard Pressed</td>
<td>22.4%</td>
<td>Urban Adversity</td>
<td>17%</td>
</tr>
</tbody>
</table>


e) Insight Value Group Scale

The Insight Value Group Scale is widely cited in popular literature on demographic classification systems (e.g. Business Balls, 2013; Mark Media, 2013), however, original sources are difficult to find. According to Somani (2006), the classification was developed by Insight Value Group Ltd on the basis of a large-scale survey in the UK. Interestingly, the Insight Value Group Scale draws on Maslow’s Hierarchy of Needs (Maslow, 1943) and offers segmentation based on personal needs and aspirations rather than professional skills or economic means. An overview of the classification system is given in Table 22.

<table>
<thead>
<tr>
<th>Value Group</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Self-actualisers</td>
<td>Focused on people and relationships, individualistic, like change and operate “in a framework of non-prescriptive consideration for others”.</td>
</tr>
<tr>
<td>Innovators</td>
<td>Self-confident risk-takers, they seek new and different things and set their own targets to achieve.</td>
</tr>
<tr>
<td>Esteem-seekers</td>
<td>Acquisitive and materialistic, they aspire to what they see as symbols of success.</td>
</tr>
<tr>
<td>Strivers</td>
<td>They attach importance to image and status as a means of enabling acceptance by their peer group, at the same time holding onto traditional values.</td>
</tr>
<tr>
<td>Content-conformers</td>
<td>They want to be “normal,” so they follow the herd and accept their circumstances. They are comfortable in a security of their own making.</td>
</tr>
<tr>
<td>Traditionalists</td>
<td>Averse to risk, they are guided by conventional behaviours and values. Quiet and reserved, they hang back and blend in with the crowd.</td>
</tr>
<tr>
<td>Disconnected</td>
<td>Detached and resentful, embittered and apathetic, they tend to live in the “ever-present now.”</td>
</tr>
</tbody>
</table>

f) Visitor Identities

Focusing specifically on museums visitors, Falk (2009) proposes that visitors come to the museum to fulfil specific identity-related needs. He understands the visitor experience as a constructed relationship each time someone visits a museum, depending on the visitor’s social interactions, prior experiences and interests and the exhibits encountered. Visitors with similar motivations and pre-visit expectations have qualitatively similar experiences and show similar patterns of meaning-making during and after their visit.

Falk (ibid) developed Visitor Identities to balance museum-centric approaches focusing on content and presentation as the main drivers for people to visit museums and visitor-centric approaches that rely on socio-demographic information to explain why people visit museums. He argues that both of these approaches are limited when used on their own, the former neglecting visitor’s previous knowledge and pre-dispositions as important factors shaping the museums experience, and the latter being too blunt an instrument to understand the visitor experience and inform programming and exhibition design.

An overview of Falk’s visitor identities is given in Table 23. Actual percentages of visitor identities vary considerably between museums (ibid). The percentages in Table 23 refer specifically to the California Science Center and are provided only to give an idea of a possible distribution of visitor identities.

<table>
<thead>
<tr>
<th>Visitor Identity</th>
<th>Visitors to California Science Center</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Facilitators</td>
<td>41%</td>
<td>Motivated by other people, e.g. parents taking their children to facilitate their learning, people tagging along in an exhibition.</td>
</tr>
<tr>
<td>Explorers</td>
<td>34%</td>
<td>Motivated by personal curiosity, they prefer to explore museums independently rather than following guided tours and enjoy informal learning opportunities.</td>
</tr>
<tr>
<td>Professional / Hobbyist</td>
<td>7%</td>
<td>Motivated by specific knowledge-related goals, professionals and hobbyists usually come to the museum with a particular purpose in mind and critically evaluate their experience.</td>
</tr>
<tr>
<td>Recharger</td>
<td>6%</td>
<td>Motivated by contemplative or restorative experience, rechargers come to the museum to take time out and enjoy the ambience and exhibits on show.</td>
</tr>
<tr>
<td>Experience Seeker</td>
<td>3%</td>
<td>Motivated by desire to see and experience places, experience seekers tick off cultural experiences and ensure they have seen every highlight.</td>
</tr>
</tbody>
</table>

Table 23: Visitor identities synthesised from Falk (2009, 2010). [not shown: 10% Other]

g) Culture Segments

Culture Segments describe different audiences in the UK cultural sector. Developed by Morris Hargreaves McIntyre Ltd, the classification system is based on a large-scale online survey involving 4,557 individual respondents (UK adults, 16+ years) interested in art,
cultural activities and events. To ensure that the sampling was representative for the UK market for arts and culture, the survey used quotas and weighted responses based on data from the Arts Council UK’s Taking Part Survey 2007/08. The classification identifies eight distinct audience types based on personal interests, attitudes and "beliefs about the role that art and culture play in their lives" (Morris Hargreaves McIntyre, 2011; p. 3).

Culture Segments provide detailed profiles that combine demographic data with information about attitudes and priorities, needs analyses and quantitative information about arts- and culture-related engagement and expenditure. Unlike Falk’s (2009) visitor identities, which describe roles that visitors take on for a specific visit (e.g. someone might be a Facilitator when taking their friend to a Fine Art gallery, but an Experience seeker when visiting a Science museum on their own), culture segments allow predictions on how likely someone is to visit a cultural venue and what they are looking for when there.

The eight culture segments are described in Table 24 together with their percentage of the UK population.

<table>
<thead>
<tr>
<th>Culture Segment</th>
<th>UK market for arts &amp; culture</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Enrichment</td>
<td>17%</td>
<td>Characterised by older adults with time to spare. They have established tastes and enjoy culture that links into their interests in nature, heritage and more traditional art forms.</td>
</tr>
<tr>
<td>Entertainment</td>
<td>14%</td>
<td>Conventional, younger adults for whom the arts are on the periphery of their lives. Their occasional forays into culture are usually for spectacular, entertaining or must-see events.</td>
</tr>
<tr>
<td>Expression</td>
<td>13%</td>
<td>Confident, fun-loving, self-aware people in-tune with their creative and spiritual side, with a wide range of interests from culture and learning to community and nature.</td>
</tr>
<tr>
<td>Perspective</td>
<td>13%</td>
<td>Settled, fulfilled and home-orientated, however their desire to learn and to make new discoveries provides a focus for engaging with arts and culture.</td>
</tr>
<tr>
<td>Stimulation</td>
<td>12%</td>
<td>Active group looking for new experiences and challenges to break away from the crowd. Open to a range of experiences, they like to be at the cutting edge in everything they do.</td>
</tr>
<tr>
<td>Affirmation</td>
<td>11%</td>
<td>Young adults, often studying or looking after family at home, for whom the arts is one of many leisure choices. They see arts and culture as a means to develop themselves as individuals.</td>
</tr>
<tr>
<td>Release</td>
<td>11%</td>
<td>Younger adults with busy working and family lives who used to enjoy relatively popular arts and culture, but have become switched off as other things have taken priority in their lives.</td>
</tr>
<tr>
<td>Essence</td>
<td>9%</td>
<td>Well-educated, highly active cultural consumers and creators, they are leaders rather than followers. Confident in their own tastes, they pay little attention to what others think.</td>
</tr>
</tbody>
</table>

*Table 24: Culture segments. Source Morris Hargreaves McIntyre (2011).*
In summary, this section has reviewed a range of classification systems used in various reports about audience and visitor research in museums. They range from domain agnostic (MRS, 2006; Somani, 2006; CACI, 2010a; ONS, 2010; Savage et al., 2013) to museum-specific (Falk, 2009; Morris Hargreaves McIntyre, 2011) and from classifications based on professional skills (MRS, 2006; ONS, 2010) or standing in society (Savage et al., 2013) to systems offering comprehensive audience profiles covering living conditions, physical fitness and consumer behaviour (CACI, 2010a), needs and motivations (Somani, 2006; Falk, 2009), lifestyles, values and aspirations (Morris Hargreaves McIntyre, 2011).

The diversity in perspectives, populations, categories and metrics used in these classification systems makes it difficult to compare or synthesise audience research based on them. It does, however, offer great potential to triangulate persona characteristics and inform scenarios of use putting them into context.

### 6.4 Personas

Personas are "archetypal people who are involved with a product or service" (Saffer, 2010; p.106). Reflecting their widespread use in user-centred design, several approaches to persona development have emerged over time. Lene Nielsen (2015) differentiates between (i) goal-directed personas, which are defined by personal, practical or job-related goals as well as their emotions when using a product, (ii) role-based personas, which focus on the users’ roles in the organization, (iii) engaging personas, which provide a holistic perspective on users that enables us to emphasise with them, and (iv) fiction-based personas, which are not informed by user research but instead are the product of the designer’s imagination to generate discussion and insights in the field. A comprehensive overview of the potential benefits of using personas suggested in the literature is provided in Miaskiewicz and Kozar (2011).

Personas presented in this section include visitor personas, who represent primary users among museum visitors, and staff personas, who represent primary users among museum staff. The visitor personas are fundamentally goal-based, however, they are enriched with personal information to make them more relatable in the tradition of the engaging perspective (Nielsen, 2015). The staff personas are primarily role based, but they also have a goal-based perspective based on their specific responsibilities in the organisation and an engaging perspective based on some personal information.

#### 6.4.1 Visitor personas

According to Nielsen (2015), persona descriptions should focus on aspects relevant to the product or service being researched. Consequently, the developed personas highlight:

- **Background and life priorities** - to motivate their attitudes to museums and lifelong learning
- **Personality** - to indicate their tendency (or not) to share their views with others and engage in public debate
- Digital literacy - to indicate their inclination (or not) to use their mobile to engage with novel technologies
- Museum habits - to indicate how often they visit museums and what they are interested in
- Interpretation habits - to indicate interest in interpretation and inclination to read and contribute visitor comments

Together, these aspects motivate and frame the developed personas' attitudes and behaviours when encountering SOLs in museums in the scenarios described in section 6.5.

The personas are not based on any specific, statistically prevalent visitor types for two reasons. Firstly, vom Lehn (2013) contends that visitor types based on classification schemes cannot be found in the real and messy context of actual museum visits. Secondly, the review of visitor classification systems (see 6.3) has shown that there are many different perspectives and approaches with little overlap, making any specific choice arbitrary. The developed visitor personas therefore reference multiple classification systems in order to triangulate characteristics from multiple viewpoints (see "Fit with audience classifications" at bottom of persona descriptions).

Consistent with Saffer (2010), the developed personas do not necessarily represent the majority of visitors, which would be futile given that each museum has a different audience composition (Falk, 2009; 2010), but a subset of specific proto-visitors most likely to use and benefit from SOLs in museums. This focus ensures that design decisions reflect in first place the requirements of core users and are not diluted from the outset by trying to cater for too wide a potential user group with conflicting interests and preferences.

Four visitor personas were developed, including one power user most likely to use and benefit from a social interpretation platform (Manuela), two occasional, relatively open-minded and tech-savvy visitors designed to support scenarios involving pairs of visitors (Sarah and Dave) and one professional, well informed visitor who is sceptical about digital technologies but might be persuaded to use SOLs due to the functionality they offer (John).

The developed visitor personas, together with relevant references to literature and audience classification systems, are presented on the following pages.
Primary user

**Manuela - "The culture vulture"**

32 years, Photographer, London

**Attitudes and life priorities [1]**
- Exploring art and culture
- Self-development
- Lifelong learning
- Experience over material goods

"London has an amazing art scene and I want to be part of it."

Manuela grew up in Italy and came to London 8 years ago to do an MA in photography at the Royal College of Arts. She now works as a freelance photographer and rents a flat in Brixton. Manuela loves London’s vibrant art scene and enjoys living in the middle of it. She is well informed and often talks about art, photography and current exhibitions with her friends. She visits exhibitions and openings about once a week, sometimes more, and often hangs out in or around museums to meet friends for coffee. Manuela critically reads object labels for exhibits she is interested in, but usually after she looked at them and made up her own mind. She likes to read visitor comments and sometimes comments herself, especially when she is touched by an exhibition or wants to make a point.

**Personality [2,3]**

- Introvert
- Extrovert
- Sensitive
- Confident
- Conforming
- Creative

Myers-Briggs Type Indicator [3]: ENTJ

Frank / Decisive / Assertive / Outspoken

Well informed, enjoys expanding her knowledge and passing it on to others.

**Digital literacy**

**Computer / Internet use**

- Uses technology to get things done.

**Social media use**

- Old iPhone, capped data
- Facebook, Twitter
- Professional website (created by friend)

**Mobile/Tablet use (data)**

**Museums habits**

- Visits: Once a week or more
- Social: Both with friends and on her own
- Likes: Modern Art, photography
- Dislikes: Crafts, stuffy history

**Interpretation habits**

- Reads labels
- Reads comments
- Writes comments

**Fit with audience classifications**

- Culture Segment [1]: "Essence: Well-educated professionals, highly active cultural consumers and creators"
- ACORN [4]: "Type 36: Financially stretched, educated young people in flats and tenements"
- Insight Value Group Scale [5]: "Self-actualisers: People oriented, individualistic, enthusiastically explore change"
- NS-SEC [6]: "Small employers and own account workers"
- NRS social grade [7]: "C1: Supervisory, clerical, junior managerial, administrative or professional"
- Falk visitor identities [8]: "Professional/Hobbyist, Explorer, Recharger"
## Primary user

**Sarah - "The experience seeker"**

23 years, Travel agent, London

### Attitudes and life priorities
- Enjoying life
- Going out
- Food and drink
- Contemporary events

*"I want to enjoy my life and culture adds that little extra."*

Sarah grew up in Essex. After completing her degree in tourism she now works as a travel agent in London. She often goes out with her friends and wants to enjoy life. Sarah hates being labelled shallow and likes to include cultural events into her busy social schedule as it adds a certain extra to her life. She visits museums about once a month, usually when she heard or read about an interesting exhibition, with a small group of friends, including her partner Dave. Sarah reads exhibit labels to find out what exhibits are about and likes to engage with interactive exhibits in the museum. If there is a chance, she reads visitor comments and occasionally writes a comment herself if she feels like it.

### Personality

<table>
<thead>
<tr>
<th>Introvert</th>
<th>Extrovert</th>
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<tr>
<th>Sensitive</th>
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<tr>
<th>Conforming</th>
<th>Creative</th>
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</table>

Myers-Briggs Type Indicator: **ESFP**
- Outgoing
- Gregarious
- Friendly
- Accepting
- Fun-loving
- Practical
- Flexible
- Spontaneous
- People-oriented

### Computer / Internet use
- Windows Phone, unlimited data
- Facebook, Instagram, Messenger
- Uses technology to stay in touch

### Social media use
- Facebook, Instagram, Messenger
- Uses technology to stay in touch

### Mobile/Tablet use (data)
- Windows Phone, unlimited data
- Facebook, Instagram, Messenger
- Uses technology to stay in touch

### Technology is part of life.
- Windows Phone, unlimited data
- Facebook, Instagram, Messenger
- Uses technology to stay in touch

### Museums habits

<table>
<thead>
<tr>
<th>Visits</th>
<th>Once every two month</th>
</tr>
</thead>
<tbody>
<tr>
<td>Social</td>
<td>Always with partner or friends, never on her own</td>
</tr>
<tr>
<td>Likes</td>
<td>Inspiring / exciting exhibitions</td>
</tr>
<tr>
<td>Dislikes</td>
<td>History</td>
</tr>
</tbody>
</table>

### Interpretation habits

<table>
<thead>
<tr>
<th>Reads labels</th>
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<tr>
<th>Reads comments</th>
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<tr>
<th>Writes comments</th>
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### Fit with audience classifications

<table>
<thead>
<tr>
<th>Culture Segment</th>
<th>ACORN</th>
<th>Insight Value Group Scale</th>
<th>NS-SEC</th>
<th>NRS social grade</th>
<th>Falk visitor identities</th>
</tr>
</thead>
<tbody>
<tr>
<td>&quot;Stimulation: Active group who live their lives to the full, looking for new experiences.&quot;</td>
<td>&quot;Type 33: Younger couples in their first home; smaller houses and starter homes&quot;</td>
<td>&quot;Esteem-seekers: Aspire to what they see as symbols of success.&quot;</td>
<td>&quot;Intermediate occupations (clerical, sales, service)&quot;</td>
<td>&quot;C1: Supervisory, clerical, junior managerial, administrative or professional&quot;</td>
<td>&quot;Experience Seeker, Explorer&quot;</td>
</tr>
</tbody>
</table>
Dave grew up in Croydon and now works as an operations manager for a large catering company at Gatwick Airport. He shares a place in the outskirts of London with his girlfriend Sarah. Dave loves sport and keeping fit. He is not too interested in museums himself but does not mind accompanying his partner together with a group of friends. Some of the exhibitions he actually finds quite interesting, although it’s not something he would discuss with his friends in the pub. Dave only reads labels and visitor comments when an exhibit piques his interest and only very rarely comments himself when he feels he has something to say.

### Personality

<table>
<thead>
<tr>
<th>Introvert</th>
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<th>Creative</th>
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Myers-Briggs Type Indicator \[^{[3]}\]; ISTJ

Quiet / Serious / Practical / Matter-of-fact / Realistic / Responsible / Logical / Organized / Traditional / Loyal / Value Traditions

### Digital literacy

<table>
<thead>
<tr>
<th>Computer / Internet use</th>
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<table>
<thead>
<tr>
<th>Social media use</th>
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<thead>
<tr>
<th>Mobile/Tablet use (data)</th>
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</table>

Technology as a status symbol.

- High-end Android phone, unlimited data
- Facebook, Twitter, Messenger
- Digital TV Home Entertainment

### Museums habits

<table>
<thead>
<tr>
<th>Visits</th>
<th>Once every two or three months</th>
</tr>
</thead>
<tbody>
<tr>
<td>Social</td>
<td>With girlfriend or larger group of friends</td>
</tr>
<tr>
<td>Likes</td>
<td>Science and Technology</td>
</tr>
<tr>
<td>Dislikes</td>
<td>Conceptual Art</td>
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</tbody>
</table>

### Interpretation habits

<table>
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<tr>
<th>Reads labels</th>
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<th>Writes comments</th>
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</table>

### Fit with audience classifications

- **Culture Segment** \[^{[1]}\]
- **ACORN** \[^{[4]}\]
- **Insight Value Group Scale** \[^{[5]}\]
- **NS-SEC** \[^{[6]}\]
- **NRS social grade** \[^{[7]}\]
- **Falk visitor identities** \[^{[8]}\]

- **Stimulation: Active group who live their lives to the full, looking for new experiences.**
- **Type 33: Younger couples in their first home; smaller houses and starter homes**
- **Strivers: Image and status as a means of enabling acceptance by peer group**
- **Intermediate occupations (clerical, sales, service)**
- **C1: Supervisory, clerical, junior managerial, administrative or professional**
- **Facilitator, Experience Seeker**
John grew up and trained as a restorer in Leicester before he moved to London, where he became involved in the antiques trade and soon set up his own shop. He always had an interest in arts and crafts and visiting museums is a fixed part of his life. He tries to visit once a month, usually on his own and during the week when it is less busy. John prefers smaller, mixed museums where he can uncover quirky items and anonymous masterpieces. He reads labels studiously and critically, drawing on and expanding his own subject knowledge. John reads visitor comments if there is a chance, but often finds them shallow or ill informed. When he writes comments it is usually to add information or, in rare cases, to correct what is written on the object label.
6.4.2 Staff personas

In addition to visitor personas, staff personas were developed to inform museum professionals’ requirements for SOLs. While these are outside the immediate research focus on the end-user experience, they are useful in the development of prototypes fit for deployment in realistic gallery environments, which typically are tightly controlled and highly sensitive to any disturbances to the visitor experience. The developed staff personas are informed by informal discussions with museum professionals as well as in-depth expert interviews exploring museum professionals’ views on SOLs (Chapter 7).

**Greg - Gallery manager**

28 years, South London Gallery, London

"Building sets and keeping the gallery running - I love my job"

Greg has been working at South London Gallery for seven years. Joining his love for theatre, sound and geeky stuff, he is most often found on top of a ladder or with a spanner in his hand. Greg provides the technical know-how for all exhibitions and events at the gallery, along with the day-to-day fixes and tweaks to its increasingly tech-laden shows. When not building Twitter printers or green screens from scratch, Greg will be writing risk assessments to keep everyone safe.

**Responsibilities**

- Designing and building gallery sets
- Working with artists to realise installations
- Developing interactive installations
- Sourcing materials and contractors
- Risk assessments (health and safety)
- Archiving exhibitions

**Digital literacy**

Loves technology, builds technology prototypes for work and for fun. Focus on getting things to work rather than optimal solutions. Regularly uses computers at work. Carries an Android phone so he can be contacted when not in his office.

References used in all four personas:

[1] Culture Segments (Morris Hargreaves McIntyre, 2011)
[8] Visitor Identities (Falk, 2009; 2010)
Chapter 6 User and scenario modelling

Primary user (staff)

Jane - Education manager

42 years, South London Gallery, London

"Opening minds keeps me going"

Jane has been with South London Gallery since the beginning. She develops programmes of education that widen participation in the arts through events, courses, workshops, learning resources and interpretation linked to exhibitions. Jane caters for all audiences including families, young people, schools and colleges, and the community. When not busy facilitating workshops or leading groups of school children through the gallery, Jane will be developing new learning materials or researching how visitors interact in the gallery.

(Description informed by http://www.tate.org.uk/about/learning/)

Responsibilities

- Developing education programmes
- Delivering courses, workshops, events
- Working with interpretation team to develop object labels and information materials for exhibitions
- Researching visitor engagement and learning

Digital literacy

Pragmatic attitude to technology. Regularly uses computer at work for research, communication and to develop learning programmes. Uses iPads in learning activities with children. Can be contacted on her iPhone when not in the office.

Reflecting the fact that staff deal with SOLs as part of their job, as opposed to visitors, whose engagement is voluntary and depends on various motivational factors, staff personas show professional responsibilities rather than personality traits and only list general attitudes to technology, while omitting any visitor characteristics such as visit frequency or commenting behaviour.

The developed two staff personas reflect key primary users on the part of museums. They include a gallery manager, who is responsible for installing, configuring and maintaining SOLs in the gallery space (Greg) and a learning manager, who is interested in SOLs as a social interpretation platform and is responsible for managing and moderating comments submitted by visitors (Jane).

6.5 Scenarios

Scenario-based design uses short fictional narratives of people interacting with a new technology in the intended target environment to inform its design and development (Rosson and Carroll, 2003). As they can describe user interaction at different levels of detail and include implicit information about contextual aspects and design consequences, they can help designers to reflect on several interrelated aspects simultaneously.
Rolland et al. (1998) point out that scenario-based design is used differently across disciplines, with HCI, software engineering, information systems and requirements engineering communities all using different terminologies and varying in their emphasis on different strengths of scenarios. The authors propose a framework with four dimensions, including form, content, purpose and lifecycle to classify the use of scenario-based methods. Taking this framework as a reference, much of the literature focuses on the purpose dimension of scenarios. In the HCI community, specific emphasis is often placed on the usefulness of scenarios in communicating the properties and functionality of new systems to stakeholders in participatory system design and development (e.g. Carroll, 1997; Bødker, 2000; Rosson and Carroll, 2003). By contrast, the requirements and software engineering communities often use scenarios in a more analytical way to understand a system's operation, involved agents, triggering events, alternative solutions and to explain the rationale behind design aspects and user behaviours (e.g. Benner et al., 1992; Haumer, Pohl and Weidenhaupt, 1998; Rolland et al. 1998). The use of scenarios in the context of this thesis aligns more with the latter perspective: while the developed scenarios informed discussions with stakeholders, including descriptions of how SOLs might be used by visitors and museum staff, they were not formally introduced as design documents, i.e. they were not handed out to participants before user studies and there was no extra time during studies to read and discuss specific scenarios. Instead, the scenarios were developed, and successively refined and extended, primarily to inform the requirements analysis by unlocking implicit information in contextual use cases and to explore usability aspects by modelling the SOL interaction from visitor and staff perspectives.

Nathan, Klasnja and Friedman (2007) point out that scenario-based design often neglects the impact of technology on secondary and tertiary users, does not take into account technology appropriation and unintended uses and fails to consider longer-term issues emerging when the technology becomes pervasive. In order to mitigate these weaknesses, the scenarios presented below incorporate key qualities of value scenarios (ibid) by including aspects relating to pervasiveness, time, systemic effects and value implications, and by involving personas who are sceptical towards mobile technologies (John) or visit museums mainly in a facilitator role (Dave) (Falk, 2009).

While fundamentally speculative, the scenarios were validated and successively refined and extended through observations in museums (Chapter 5) and findings from design and evaluation activities involving users and museum professionals (Chapters 7 and 8). This continued development addresses Rolland et al.’s (1998) lifecycle aspect of scenarios and manifests itself in variations describing alternative functionality and user actions, resulting in a branching structure that reflects the iterative development process and covers a range of possible interactions informed by user research. While examples of scenarios in the literature typically introduce characteristics of their actors at the beginning, the scenarios presented here omit this for the sake of brevity and assume instead that readers are familiar with the actors from the persona descriptions above (see 6.4).

Findings from Scenarios [FSn] are marked in context [FSn] and listed after each scenario.
Scenario 1

Scenario 1 involves Manuela (see 6.4.1), a potential power user, encountering a SOL in an exhibition and carrying out a range of typical user tasks. It also describes variations in SOL functionality and user behaviour based on various prototypes and observations.

Manuela is in Tate Modern to see a newly opened Op Art exhibition. Walking through the gallery, she stops in front of a large Bridget Riley canvas. After taking in the image for a while, she reads the label, which provides the image title and some information on materials, process and contemporary reactions. Next to the label, she notices a SOL indicating 37 comments for the artwork and showing information to connect a mobile device [FS1]. Curious to find out more, ...

a) ... she gets out her mobile phone and touches the NFC symbol [FS2].
   a1) She has used SOLs before in another gallery and knows this works with her phone.
   a2) When nothing happens, she goes into her phone settings and enables NFC before trying again. This time it seems to work.

b) ... she gets out her mobile phone and scans the QR code [FS2]. She recently was shown by a friend how to use QR codes and is relieved that it actually works.

c) ... she gets out her mobile phone. As she is not familiar with NFC and only vaguely knows how QR codes work, she types the URL shown on the SOL into her browser’s address bar [FS2].

Her phone, which automatically connects to the gallery’s free Wifi since she set it up a while ago, shows her a thumbnail image [FS3] of the Riley canvas and a list of visitor comments [FS4]. Manuela reads the comments and ...

a) ...although she is annoyed by the large proportion of trivial messages she thinks that overall they provide a nice contrast to the professionally written museum label.

b) ...although she finds some comments quite interesting, she is annoyed by the large proportion of trivial messages. Noticing the small “Thumbs up” and “Thumbs down” buttons below each comment, she is quick to vote up the ones she likes best [FS5, FS6]. Overall she likes the idea of having visitor’s thoughts next to the professionally written museum label and appreciates that she can make her voice heard.

c) ...after a while comes across a comment she finds very offensive. Without hesitation, she hits the "Flag" button to report the comment for moderation [FS7]. She adds a short message to the moderator explaining why she finds the comment offensive and submits it [FS8]. This brings her back to list of comments, with the flagged comment being replaced by an automated message that it is currently being moderated [FS9].

She hits the "Add Comment" button at the bottom of the screen and writes her own comment [FS10] describing the difference between seeing a reproduction in a book and experiencing the actual image in the gallery.

a) She adds her name in the optional field below here message and hits submit [FS11].

b) She notices that the system automatically remembered her name from a previous visit and hits submit [FS11].

After submitting the comment, she looks at the SOL to confirm that the counter ticked up and now stands at 38 comments [FS12]. Happy to have her comment on the system, she sees that it appears top of the list on her mobile phone [FS6].
Re-reading her comment, she notices that she has made a spelling mistake. As the system knows that it is her comment, it shows an "Edit" button instead of the "Flag" button for her comment. She hits "Edit" and finds herself back in the commenting screen where she corrects her mistake and re-submits.

Having made her point and knowing that others can see her comment on the system, Manuela feels empowered and engaged and eagerly moves on to the next canvas.

Findings from this scenario include:

FS1: SOLs should display information on how to connect a mobile device.

FS2: SOLs should support multiple methods and technologies to connect a mobile device.

FS3: The mobile app should display an image or other visual clue that confirms to visitors that they are connected to the right SOL and exhibit.

FS4: SOLs should enable visitors to read comments on their mobile device and on the situated display.

FS5: SOLs should enable visitors to rate existing comments.

FS6: The order in which comments are shown should reflect their recency and community rating.

FS7: SOLs should enable visitors to flag comments for moderation.

FS8: When visitors flag comments, SOLs should enable them to add a message to the moderator explaining the reasons why it was flagged.

FS9: SOLs should immediately hide flagged comments and instead display a message explaining that they are under moderation.

FS10: SOLs should enable visitors to post comments in-situ.

FS11: SOLs should provide an option for visitors to provide a name with their comment. The optional name field should be automatically populated for repeat users.
Scenario 2

Scenario 2 involves Sarah and Dave (see 6.4.1) as a prototypical couple visiting a gallery. It incorporates research on visitor types (Kuflik and Dim, 2013) and observations of couples in galleries. It involves an advanced prototype supporting direct interaction on the SOL screen.

Sarah and Dave are in the Serpentine Gallery after reading about its new exhibition in the Sunday paper. There are some challenging sculptures and installations in the gallery space. Sarah loves being perplexed by art and eagerly reads the object labels to find out about the exhibits and the artist. In her quest for more information about a specific installation involving brightly painted oil drums she comes across a SOL and starts to read through visitors' comments [FS4]. She realises that this is not curated or verified information [FS15] and is keen to read through other people's reactions, some of which seems to support her own views. Meanwhile, Dave, who is not very interested but had patiently followed her around, ...

a) ... looks over her shoulder to see what Sarah does on the SOL.

b) ... spots the NFC symbol on the SOL Sarah is operating [FS2]. Always happy to play with new technologies, he gets out his high-end mobile phone and taps the tag with it [FS16]. As he has an unlimited data plan, there is no need to connect to the gallery's free WiFi network [FS17] and the comments show up straightaway.

Reading some of the comments makes him look at the exhibit more critically and read the label. Noticing that the label refers to "oil barrels", he is excited to have found an obvious mistake, as he knows from a previous job that "barrel" is only a unit for oil while the actual container is called a "drum" [FS18].

a) As a regular Twitter user he had spotted the Twitter symbol on the SOL, so he sends off a tweet about the mistake using the hashtag shown on the SOL.

b) Having the list of comments still on his mobile, he submits his own comment pointing out the mistake.

Sarah, still absorbed in reading visitor comments, sees Dave's comment popping up on the SOL [FS6, FS11, FS12] and, recognising his ...

a) ... Twitter handle ...

b) ... name ...

... asks him astonished whether he posted that. He smiles and is happy to show her how the mobile interaction works.
Additional findings from this scenario include:

<table>
<thead>
<tr>
<th>FS15</th>
<th>SOLs should clearly mark visitor comments as content submitted by users and not provided by the gallery.</th>
</tr>
</thead>
<tbody>
<tr>
<td>FS16</td>
<td>SOLs should support multi-user scenarios, e.g. enable a user to connect their mobile device while another visitor interacts with the in-situ display and enable multiple mobile devices to be connected at the same time.</td>
</tr>
<tr>
<td>FS17</td>
<td>SOLs should be able to operate on both WiFi and mobile data networks to minimise friction for visitors with or without a data plan when connecting their device.</td>
</tr>
<tr>
<td>FS18</td>
<td>SOLs should enable users to refer to another comment, e.g. by providing unique comment markers (e.g. user name and date) an author can reference.</td>
</tr>
</tbody>
</table>

**Scenario 3**

Scenario 3 involves John (see 6.4.1) visiting a museum on his own during the week. It draws on observations and visitor interviews (Chapter 5), and involves different prototypes with and without support for direct interaction on the SOL display.

It's a rainy Thursday morning and John, having a spare two hours before meeting a client, is at Brighton Museum to see a particular piece of Art Deco furniture similar to the one he is restoring at the moment. He often visits the museum and has seen the piece several times before.

a) Noticing the newly installed SOL next to the traditional object label, he is curious to find out what it is. He sceptically looks at the NFC symbol and QR code as "modern stuff not from his generation", but recognises the URL as something to enter in his browser's address bar [FS2]. Being alone in the gallery and having time on his hand, he decides to give it a shot. He gets out his mobile phone and puts on his reading glasses [FS19]. After typing the URL in the browser's address bar he is surprised that it actually works and shows him a list of comments. Browsing through the comments, he spots a question by a visitor asking about the type of wood used in the exhibit. He knows all about the materials the piece is made of and is keen to answer the question [FS20]. As his focus shifts from awkward technology experience to sharing his subject knowledge, John does not hesitate to hit the large "Add Comment" button at the bottom of the mobile screen and submits a short factual comment explaining that the piece is made of cherry wood.

b) Noticing the newly installed SOL next to the traditional object label, he is curious to find out what it is. Guided by the large touch icon on the SOL, he tentatively touches the e-ink screen, even though it seems switched off to him. The SOL briefly flickers and displays a visitor comment and two big navigation buttons. After reading the comment, John taps the navigation button to see more comments. One of them asks about the type of wood
used in the exhibit. He knows all about the materials used in the piece and is keen to answer the question [FS20]. He touches the “Add Comment” icon at the bottom of the display, which leads him to a help screen [FS21] explaining that comments can be added using a mobile phone. John hesitates. He does not like “this modern stuff” but feels an urge to impart his professional knowledge. Reading through the help screen [FS22], he quickly discards NFC, QR codes and Twitter but feels fairly confident about entering a URL into his mobile phone [FS23]. He gets out his mobile phone and puts on his reading glasses [FS19]. After typing the URL in the browser’s address bar he is surprised that it actually works and shows him a list of comments. He scrolls down to verify they are the same comments as on the SOL and then hits the “Add Comment” button to submit his own comment explaining that the piece is made of cherry wood.

c) Looking at the SOL where he submitted a comment last time, he notices that the comment count is much higher than he remembered. Curious to see what’s new and remembering how it works, he is quick to type the URL into his mobile browser and read through the latest comments [FS23]. One of them, marked as being from museum staff [FS24], thanks him for his contribution and states that the object label has been updated accordingly. Proud to see his contribution acknowledged, he re-reads the updated object label, which now mentions cherry wood as the main material.

Additional findings from this scenario include:

| FS19: | SOLs should display content in a large enough font size for people with weak eyesight on both the SOL display and the mobile application. |
| FS20: | SOLs should enable visitors to reply to comments. |
| FS21: | SOLs should provide a help screen explaining that, and how, comments can be added with a mobile device. |
| FS22: | The SOL help screen should explain in detail the different ways to connect a mobile device. |
| FS23: | Comments should be presented in reverse chronological order. |
| FS24: | SOLs should clearly mark comments by museum staff so that visitors can distinguish between the visitor voice and the museum voice. |

Scenario 4

Scenario 4 involves Greg (see 6.4.1) as a gallery manager installing and maintaining SOLs in the gallery. It draws on discussions and expert interviews with museum professionals (Chapter 7) as well as experiences during field trials (see 8.3 and 8.5).
Chapter 6 User and scenario modelling

It's the last week before the new exhibition opens and Greg finally has received the new SOL casings matching the exhibition design [FS25]. He already has set up the exhibits on the Web-based SOL dashboard [FS26] and now needs to install and register the SOLs for each exhibit [FS27]. He gets the SOLs out of the cupboard and switches them on one by one to verify that they work. The SOLs automatically switch into configuration mode and indicate that they are fully charged and connected to the internal WiFi network [FS28,FS29].

Going round the gallery, Greg fixes a casing next to each exhibit, slots in the SOL display and connects it to mains power [FS30]. He then enters the exhibit ID in the configuration screen [FS27], selects the agreed display layout from a drop-down list and double-checks the indicators for WiFi signal strength and battery status before hitting the Activate button, whereupon the SOL enters the idle state ready for visitor interaction.

At one of the exhibits, where no mains power is in reach, Greg decides to run the SOL on battery instead [FS30]. He knows that SOLs last on average 16 hours in the selected configuration and resolves to swap out the display for a fully charged one each morning before the gallery opens to visitors. He knows that in case he forgets the SOL backend notifies him by email when the battery runs low [FS32,FS34], which is routed to his mobile phone so that he can react wherever he is.

Later that day, after all SOLs are set up and configured, Greg is in his workshop when he gets an email message on his mobile phone informing him that one SOL, identified by the exhibit name, seems to be offline [FS33,FS34]. He opens a browser window and navigates to the online dashboard to double-check the status of the SOL [FS35]. Here, too, the SOL is marked as offline, so he walks over to the gallery to check up on it. When approaching the SOL he notices the "disconnect" status icon on the SOL display [FS29]. He applies the admin touch sequence, which brings up a login screen, and after entering his credentials gets to the configuration screen [FS36]. He successfully reconnects to the WiFi network [FS37], however, the configuration screen indicates low signal strength [FS29]. In order to avoid future connection problems, he repositions the SOL on the other side of the exhibit closer to the hotspot. The indicator now shows a stronger signal. Greg is happy with this and hits the Activate button to put the SOL back into idle mode ready for visitor interaction.

Additional findings from this scenario include:

| FS25: | SOLs should be customisable with different casings that integrate with the overall exhibition design. |
| FS26: | The SOL backend should provide an admin dashboard for "minting" IDs (Kindberg, 2002) and creating digital resources for exhibits. |
| FS27: | SOLs should provide functionality for dynamic registration to exhibits. |
| FS28: | SOLs should have a dedicated configuration mode. |
| FS29: | SOLs should indicate their status, including their battery level, connection status and WiFi signal strength. |
| FS30: | SOLs should support battery and mains powered operation. |
Chapter 6 User and scenario modelling

FS31: SOLs should support different layouts and dynamic layout switches.

FS32: SOLs should periodically report their battery status to the backend.

FS33: SOLs should periodically ping the server to enable detection of loss of connectivity.

FS34: The SOL backend should notify administrators via suitable channels when the battery runs low or when the SOL loses network connection.

FS35: The SOL admin dashboard should provide status information about SOLs, including battery level, connection status, number of comments and interaction statistics.

FS36: SOLs should provide a password-protected way to activate the configuration mode.

FS37: The SOL configuration mode should support functionality to manage network connections.

Scenario 5

Scenario 5 involves Jane (see 6.4.1), a learning manager interested in SOLs as a social interpretation platform and responsible for managing and moderating submitted comments. It draws on discussions and expert interviews with museum professionals (Chapter 7).

The new exhibition has been running for a few days and Jane is curious to find out what people think. She logs on to the online dashboard where she is presented with an overview of all SOLs in the exhibition [FS38, FS39]. Besides technical information indicating connection status and battery levels, the dashboard shows how many comments were submitted to each SOL and how often people connected their mobile device [FS35]. Jane is surprised that one lesser known exhibit apparently strongly resonates with visitors as it received more comments than the more prominently featured exhibits. She clicks on the comment counter, which brings up a list of all visitor comments for that piece [FS40].

a) Jane is excited to see that an interesting debate seems to be unfolding about the exhibit, with many visitors taking a critical stance about its technical quality while many others praise its audacious message. She thinks the discussion would be of interest to people looking up the exhibition on the gallery’s website, and sends an email to the communications officer asking him to integrate the RSS feed of the comments into the exhibit’s web page [FS41].

b) Jane is disappointed to see that many of the comments are spam. She uses the moderation tools to hide the spam comments, which reduces the comment count shown on the SOL and avoids visitors having to scroll through spam before being presented with...
genuine comments [FS40].

Later that day, Jane receives an email sent out by the SOL backend with a moderation request [FS42]. A visitor has flagged up a comment as offensive and added a short message explaining her reasons [FS7, FS8]. The email identifies the exhibit where the comment was submitted and also includes the actual comment text [FS43].

a) Jane agrees that the comment is offensive and clicks the "Block comment" link at the bottom of the email [FS44].

b) Jane disagrees that the comment is offensive and clicks the "Unblock comment" link at the bottom of the email [FS44].

Clicking the link opens a simple confirmation page in her browser informing her that the comment was successfully (un)blocked [FS45].

Additional findings from this scenario include:

FS38: The SOL admin dashboard should support user management and logins to give administrators access to their organisations SOLs.

FS39: The SOL admin panel should provide an overview of all SOLs installed in an exhibition.

FS40: The SOL admin panel should provide access to visitor comments and moderation tools.

FS41: The SOL backend should provide RSS feeds of comments per exhibit.

FS42: The SOL backend should notify administrators in real-time via email or other suitable channels when a comment is flagged by visitors for moderation.

FS43: Moderation requests should contain enough information for moderators to make a decision on the spot.

FS44: Moderation requests should provide suitable back-channels to instantly block or unblock visitor comments.

FS45: The SOL backend should provide feedback to moderators indicating whether a comment was successfully blocked or unblocked.
6.6 Limitations

The scenarios in this chapter were developed primarily to support the requirements analysis and identify possible usability issues with planned functionality. While they helped to formulate and convey how SOLs would be used by visitors and museum staff, they were not formally presented and discussed during user studies, which might have helped to validate them more rigorously and engage participants more deeply in the design process.

With regard to validity, scenario-based design is necessarily subjective and arbitrary to some degree. To reduce potential bias, the persona and scenario development is informed by literature throughout and incorporates findings from observations and interviews. In order to address criticism of scenario-based design as not being critical enough and failing to envision systemic effects of new technologies, the developed scenarios incorporate aspects of value scenarios (Nathan, Klasnja and Friedman, 2007) with regard to potential problems, unexpected uses and wider impact of SOLs.

With regard to transferability, many of the requirements also apply to other display concepts. While they are identified in scenarios where personas interact with SOLs, the described problems are not necessarily specific to SOLs but often arise from a mismatch between system features and the persona's motivations, technical capabilities and digital literacy. As such, they might also be encountered with other types of public, interactive displays and related findings might equally inform other development efforts.

6.7 Conclusions

This section first developed visitor and staff personas to represent primary users of SOLs from audience and museum perspectives, and then constructed a series of scenarios in which the personas interact with SOLs to inform the requirements analysis and identify problems with design choices.

Following recommendations in the literature, the developed personas do not necessarily represent prevalent visitor types, which are differently defined across studies and vary for each institution, but archetypal users most likely to use and benefit from SOLs, informed by audience research and referenced against classification systems in the literature.

The developed scenarios are not static stories of potential uses of SOLs as conceptualised at the outset of the development process. Instead, they continually evolve to incorporate findings from on-going user research and field trials and to contextualise and evaluate planned enhancements and functionality before they are implemented. This is reflected in their branching structure that explores alternative user actions and technologies.

The scenarios helped to identify a wide range of requirements relating to the SOL display, the related mobile application, the administration interface and related backend services. The requirements are referenced in the scenarios and listed immediately afterwards to ground them in the use context from which they arise and thereby aid comprehension.
7 Expert interviews

7.1 Introduction

In addition to numerous informal discussions, some of which are reported on in 8.2, a number of formal interviews with museum professionals were carried out to inform the requirements analysis from the viewpoint of museums and obtain feedback on the developed prototypes. The interviews were carried out between January 2014 and February 2015. They involved information materials explaining how SOLs might be used in the gallery space and how they are set up and maintained, mock-ups illustrating alternative designs and configurations, and working prototypes at various stages in the development process (v.5 - v.7) for interviewees to try out. The materials helped to provide the necessary context and background information for an informed discussion focusing specifically on in-gallery commenting with SOLs.

7.2 Methodology

A total of seven in-depth interviews were carried out with museum professionals from Science Gallery Dublin, Regency Townhouse and Phoenix Gallery Brighton. In order to cover a broad spectrum of views concerning the deployment, maintenance and integration of SOLs into existing practices and workflows, interviewees with different responsibilities were selected, with roles including Technical Manager, Web & IT Manager, Programme Manager, Marketing and Communications Manager, Researcher, Director and Co-Chair. Interviewee identifiers, used in the following sections to attribute specific answers, are listed in Table 25 together with their organisational roles for context.

<table>
<thead>
<tr>
<th>Interviewee</th>
<th>Role</th>
</tr>
</thead>
<tbody>
<tr>
<td>I1</td>
<td>Gallery Director</td>
</tr>
<tr>
<td>I2</td>
<td>Programme Manager</td>
</tr>
<tr>
<td>I3</td>
<td>Researcher</td>
</tr>
<tr>
<td>I4</td>
<td>Technical Manager</td>
</tr>
<tr>
<td>I5</td>
<td>Marketing and Communications Manager</td>
</tr>
<tr>
<td>I6</td>
<td>Web &amp; IT Manager</td>
</tr>
<tr>
<td>I7</td>
<td>Co-Chair</td>
</tr>
</tbody>
</table>

Table 25: Interviewee identifiers and roles in their organisations

The interviews were semi-structured, discussing a fixed set of questions and further exploring relevant aspects as they emerged. The fixed interview questions related to moderation, attribution, conservation and reuse of content, openness of the system, backend requirements and deployment aspects (see Appendix E for specific questions). The interviews were carried out in person (2), by email (1) and via video link (4). Interviews in
person and via video link lasted between 32 and 54 minutes. Some were audio recorded and transcribed (4) while others involved the researcher taking notes (2), which were amended and clarified from memory directly after the interview. Answers from all interviews were aggregated under their respective question headings and common themes were identified in the process.

The following section discusses domain experts' views on specific interview questions and identifies related requirements for SOLs (Findings from eXpert interviews [FXn]) relating to the actual display, the mobile application and backend services.

7.3 Findings

7.3.1 Content moderation

Content moderation is a critical aspect of any system publicly displaying comments or other expressive content submitted by users and interviewees' answers ranged from cautious and restrictive to tolerant and open. In answer to the question "How should we deal with inappropriate or offensive comments?" one interviewee (I7) pointed out that there was an issue with public liability. As most galleries are publicly funded, they might have an obligation to pre-moderate comments before showing them in the gallery. However, as this requires someone to do it, which in turn costs the museum money, the same interviewee argued that from this point of view post-moderation might also be acceptable.

Several interviewees questioned how much of a problem inappropriate content actually would be when running such a system in the gallery space, with some participants pointing out that visitors act more responsibly in the gallery space than when online, and others arguing that offensive content is "not the end of the world" (I4) as long as it is removed in a reasonable time frame. The former is supported to some extent by literature indicating that museum visitors actually post less offensive content in the gallery space than expected (Gray et al., 2012).

Against this backdrop, most interviewees spoke out in favour of a post-moderation model, i.e. moderating and removing inappropriate content after it was posted and made publicly available on the system, supported by users flagging offensive content. One key argument mentioned in favour of post-moderation is that it requires fewer resources and eliminates the inevitable delay in pre-moderation between posting a comment and it becoming visible on the system, thereby resulting in a more immediate user experience. It was pointed out that user-supported post-moderation follows best practice on large social networks and discussion sites on the Web and therefore should be familiar to most users. The suggested model integrates well with current workflows, where staff keep an eye on the gallery space and routinely check user-generated content once or twice a day. This process can be supported by users flagging up comments they find objectionable and thereby directing moderators' attention to problematic content.
Rather than having a dedicated content moderator, responsibility to react to user-flagged content is likely to be distributed among a team of moderators on call. In larger institutions this is likely to include technical, IT and communications staff whereas in smaller places this is likely to include the gallery manager and volunteers. In order to shorten response times and eliminate the need for moderators to repeatedly check whether content was flagged, the system should notify relevant staff when content is flagged. Ideally, notifications are delivered not only to staff's desktop but also to their mobile device so that they can react quickly even when not at their desk.

| FX1:   | The system should enable moderators to browse user-generated content without the need to be present at the related object |
| FX2:   | The system should enable moderators to react to moderation requests, i.e. to find, read, block and un-block flagged content |
| FX3:   | The system should enable users to flag content for moderation |
| FX4:   | The system should notify moderators when content is flagged by users. Notifications should be sent to moderators' desktop and mobile devices |

As suggested in particular by interviewees with IT backgrounds, technical measures already used on the museums’ website could be used to help avoid inappropriate content being posted on the system. These include automated screening of submitted content, for instance with Mollom22 or Akismet23, which are specialised online services to block spam and offensive posts in content management systems such as Drupal24 or Wordpress25, and logging IP addresses of contributors in order to be able to block sustained abuse by specific users. However, as both of these measures focus more on spam and automated attacks than on offensive content, they might be less relevant for content generated in-situ and less effective for mobile devices which are dynamically assigned a new IP address each time they connect to a different mobile or WiFi network.

### 7.3.2 Content metadata

Content metadata associated with a comment, such as the contributor's name, age, gender, etc. can play an important role from both the contributor's and the reader's point of view.

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From a contributor's perspective, identifying marks such as a name or username denote authorship and go some way to acknowledge moral rights to the comment (actual copyright is discussed in 7.3.4). From a reader's perspective, such metadata can potentially help to contextualise comments by providing background information about the author that might explain their expressed views.

When asked whether comments should include author-related metadata, none of the interviewees brought up the aspect of establishing authorship and moral rights of the contributor. Instead, answers discussed the actual merits of metadata from a reader's perspective and considered the user experience of providing such data. With regard to the former, it was pointed out that author-related metadata often gives only “an illusion of context” (I2) but in fact does little to help our understanding of a statement and might possibly even hinder interpretation by bringing into play prejudice based on stereotypes, e.g. ageism. With regard to the latter, most interviewees emphasised that entering additional metadata should not be a barrier to submitting comments. It was also pointed out that visitors should not feel that the institution is collecting data about them as this might prevent them from engaging, and that identifying markers (e.g. name, age, where from) are expected only in certain cultures but might not be seen as necessary or even appropriate in others. Several interviewees suggested that an optional name and the comment itself would be an appropriate balance between satisfying the convention of identifying marks associated with a comment and streamlining the user experience.

| FX5: The system should not require users to provide additional information about them when submitting comments |
| FX6: Entering meta-data should not be a barrier to contribute content |

Author-related metadata is typically drawn from user profiles and therefore closely linked to logins and online identity. A second interview question in this context was therefore whether people should login in order to submit comments. Interviewees broadly agreed that any login should be optional and no barrier to participation.

| FX7: The system should not force users to register and login |

Third-party logins, which do not require users to create an account on the system but still uniquely identify them, were seen as problematic. While they give instant access to a user's profile information and allow conversations to be easily carried over to their social network, they exclude people who do not use these services and might alienate those who would rather not connect their social network identity with their in-gallery commenting.

| FX8: The system should not rely on third-party logins |
7.3.3 Openness of the system

From a user perspective, the openness of an in-gallery commenting system is largely defined by the degree to which it supports content export and import. Users posting comments to the system might want to be able to forward and reuse them on other platforms and networks, e.g. their social network. Vice versa, users might want to post comments regarding specific artworks while not present in the gallery space, e.g. when they visit the museum’s website. The latter, discussed under the term “tetheredness” in Memarovich et al. (2013), opens up completely new use cases that mix in-situ and remote content creation, but it also and entails numerous problematic issues ranging from content quality to users’ conceptual models of the system.

When asked whether people should be able to post their comments not only to the display but also to their social network, most interviewees agreed that social media integration is generally good as it might help drive traffic to the gallery’s website. Some pointed out that this is how discourse happens these days and that most museums rely on social media to engage audiences and disseminate news. However, it was also pointed out that social network integration could turn the process of commenting into a relatively complex interaction, and that some visitors might prefer to use their default social network applications for this process rather than built-in functionality in a custom commenting application. Several interviewees concluded that social network integration would be nice to have but was not strictly necessary. One interviewee suggested that propagation to social media, specifically the museum’s social media feed, should happen automatically without requiring additional user interaction.

The idea of remote content creation, where online visitors are able to post comments to in-gallery displays, received mixed responses from interviewees. On the positive side, it could help to bridge the gallery- and online-experience of an exhibition, potentially leading to live conversations between people on the website and in the gallery. With suitable in-gallery notifications when someone posts a comment online, this could even be exploited to stir interest and increase visitor participation in the gallery space. Furthermore, remote commenting would give repeat visitors, who might develop an informed opinion on the subjects in an exhibition, an opportunity to discuss them more in-depth than would be possible with in-situ commenting using a mobile device. On the negative side, it might lead to more spam and offensive content as people are less inhibited online than in the gallery space. Overall there might be a limited returns from implementing such functionality as people are more likely to comment on their social network than on the institution’s website. Returning to the original idea of SOLs as an in-gallery commenting system, some interviewees pointed out that its purpose is to increase engagement while visitors are physically in the space and commenting should therefore require visiting the gallery and experiencing the work there. This view was summed up by the statement that “The system is specialised on in-gallery commenting and should not dilute that purpose by trying to be a Swiss Army Knife” (I6).
7.3.4 Ownership and reuse of content

Ownership, storage and potential reuse of user-generated content are important aspects from both legal and motivational perspectives. Like any original work, user-generated content is automatically covered by copyright and has associated moral rights (IPO, 2015). While attribution goes some way to acknowledge authorship and moral rights, and thereby to address motivational aspects of visitors submitting comments and feedback, actual control over content can lead to de-facto ownership. This aspect has been pointed out by (Benkler, 2002) with regard to the co-production of content and it is supported by findings from the museum visitor survey (Chapter 5) showing that many visitors link ownership of user-generated content to ownership of the medium in which content was submitted. For instance, many visitors think that a museum owns the comments in a visitor book because it owns the physical book. Informing visitors about the institution’s policies governing submitted content might help to increase transparency in this respect and lead to more equitable participation.

Concerning the long-term storage and possible reuse of user-generated content, some interviewees suggested that comments should be archived together with an exhibition and become part of their online documentation. One interviewee (I7) suggested they could even be stored on a small USB stick and attached to the physical exhibit when archived. While there were concerns as to how relevant archived comments would be once an exhibition has ended, some interviewees suggested that their main value post-exhibition would be as a data source for evaluation and reporting, especially as such data is required when applying for funding. In this context any data related to engagement and impact is useful, including analytics data from related web sites.

Some interviewees pointed out that because they do not know at this point how they might want to use comments in the future, they ideally would have the right to reuse comments in whatever context and format they think is suitable. With regard to touring exhibitions, some interviewees suggested that comments should travel with an exhibition while others pointed out that they probably would not because the exhibition would be presented as something new and showing comments from a previous instantiation would destroy that perception.

Informing visitors about the institution’s policies governing the storage and potential reuse of comments, some interviewees acknowledged that this is a sensitive point and suggested there should be a clear signal of intent on the part of the institution to make it "crystal
clear” (I2) to participant what’s being done with their information. In particular this should clarify if there are any plans for commercial uses, for how long comments are archived and who will have access to submitted information, e.g. whether comments are seen by curators or given to the artist. The majority of interviewees, however, were less concerned with these issues and emphasised the need for lightweight approaches. Suggestions in this vein included having a sign at the entrance, displaying a Creative Commons logo in the mobile application, integrating an unobtrusive notice into the visitor prompt and generally doing only the “absolute minimum” (I4) so as not to create a barrier to participation.

| FX12: | The system should store comments and interaction statistics in an open format to support data analysis and unspecified future uses |
| FX13: | Users should be informed about how their comments might be used, in particular with respect to access, archiving and commercialisation |
| FX14: | Terms of content ownership and reuse should be displayed in an unobtrusive way that does not create a barrier to participation |

7.3.5 Backend requirements

Backend requirements are based on functional needs of institutions and users of the system. While some of these have been discussed above (e.g. the requirement to notify moderators when users flag comments), this part of the interview focused specifically on content moderation and syndication via an administration interface (dashboard).

As one interviewee put it, the dashboard should be a “one-stop-shop for non-technical people to moderate comments” (I3). There was broad agreement that it should have functionality to quickly and easily browse, read, hide, delete and reset comments flagged by users. One interviewee suggested additional functionality in the form of a live feed that would enable moderators to scan comments as they are submitted (I6). The usefulness of such a feature obviously depends on the regularity and volume of content submissions.

| FX15: | The system should provide an easy-to-use dashboard suitable for content moderation by non-technical staff |
| FX16: | The dashboard should offer functionality to browse, read, hide, delete and reset comments flagged by users |

Most interviewees agreed that the user-generated content should be available for export and integration into websites in open, simple and commonly used formats such as RSS or JSON. Some pointed out that it would be good to have access to comments at exhibition level (i.e. all comments for exhibition) and object level (i.e. comments for exhibit).
Chapter 7 Expert interviews

FX17: The system should make content available in an open, easy and commonly used format such as RSS or JSON

FX18: The system should support content syndication with different scopes, including an exhibition and object scope

7.3.6 Deployment and maintenance

Deployment in the gallery space is a critical aspect for SOLs with wide-ranging design implications. Not only do they have to comply with health and safety regulations and the policies of the institution, but they also need to fit with curators’ visions for an exhibition and technicians’ views on what is viable and practical in the gallery space.

When asked how peripheral or prominent SOLs should be in the gallery space, most interviewees indicated that (in their intended use as an exhibit-level commenting platform) they should be unobtrusive and discrete so as not to distract from the work but not be so discrete that they completely disappear. One interviewee suggested that even unobtrusive displays would be used as visitors are “naturally inquisitive and explore technology bits in exhibitions” (I3). Others suggested putting up signage explaining the purpose of the system, which again should be as discrete as possible.

FX19: Displays should be unobtrusive and not distract from the exhibit

Several interviewees expressed a preference for e-ink displays, referring to a prototype used in the introduction to the interview. Their main argument for (passive-light) e-ink technology was that it is not as attention-grabbing as (active-light) screens, which can monopolise some visitors’ attention for extended periods.

FX20: Displays should use e-ink screens

The size of the current e-ink prototype (6 inch display) was seen as appropriate by most interviewees, with the suggestion that SOLs could be scaled down in the future once there are more widely adopted mobile access technologies available that eliminate the current need to offer multiple access options (QR code, URL, NFC). One interviewee (I7) pointed out that the prototype used in the interview [flat cardboard casing v.7] was too big when she imagined it next to smaller and more delicate exhibits.

FX21: Displays should be large enough to show multiple connection options for mobile access

FX22: Display sizes should be appropriate for exhibits, e.g. smaller versions should be available for small exhibits
Look and feel was pointed out as one of the most important aspects with one interviewee warning that SOLs must “not look like an e-reader in a box” (I4) and another urging to “make sure it looks as slick as it possibly can” (I3). Ideally, SOLs should look “like a continuation of the signage to read some comments” (I2). One interviewee pointed out that a slanted display mount would be more ergonomic to use for people of different heights (e.g. children).

FX23: Displays should be presented in a way that is visually pleasing and integrates with the exhibition design
FX24: Displays should be mounted appropriately for ergonomic use by people of different heights

While interviewees from a larger organisation were clear that they would develop their own display enclosures that fit in with the exhibition design, others from smaller organisations preferred SOLs to come complete with enclosure and battery ready to mount. Similarly, interviewees from the larger organisation were positive that they would plug the display into a mains power supply, while interviewees from smaller organisations prefer SOLs to be battery operated as installation is one of their main concerns.

FX25: Displays should be offered with or without casings depending on the preferences of the host organisation
FX26: Displays should support mains- and battery-powered operation

7.4 Limitations

With regard to validity, the findings discussed in this section are based on only seven expert interviews, however, due to their different roles and organisations participants' answers reflect a wide range of perspectives and experiences. The study makes no claim to exhaustively treat the discussed topics or to quantify results. Rather, it uses the issues, concerns and preferences raised by museum staff as an indication for required design features and functionality. A larger sample size would be likely to add to but not invalidate identified requirements.

With regard to transferability, many of the findings reflect general concerns and constraints of museum environments and might equally inform the development of other interactive, digital installations aiming to engage visitors in curated gallery spaces.
7.5 Conclusions

The interviews with domain experts uncovered a wide range of organisational needs and preferences informing the design of SOLs, the related mobile application and backend services. Museum professionals’ particular perspective on visitor engagement and their experience in deploying and maintaining interactive systems in the gallery space provide valuable insights that complements the end-user perspective explored in other design and evaluation activities discussed in this thesis. While some of these aspects are outside the core focus of the research, which primarily investigates how end-users engage and interact with SOLs, they are needed to develop the prototype to a professional level where it can be deployed and evaluated in real gallery environments without adversely affecting the visitor experience.
Chapter 8 Prototype design and evaluation

8 Prototype design and evaluation

A defining characteristic of design research is that it revolves around the development and successive refinement of design artefacts in an iterative process. This chapter describes the design and evaluation of SOL prototypes, the main design artefacts in this thesis research, ranging from early proof-of-concept versions to fully working prototypes fit for deployment in authentic gallery environments.

The following sections explain the starting point and trajectory of the iterative design process, describe the early prototype development (v.1-4), report on a first field trial of SOLs in an authentic gallery environment involving prototype v.5, discuss formative user testing and co-design sessions involving SOL prototype v.6 and describe in detail a second field trial in a museum setting involving prototype v.7. An overview of technical details all SOL prototypes produced in this thesis project is available in Appendix A.

8.1 Starting point and trajectory

As indicated in the introduction to this thesis (see Chapter 1), the original motivation for the research is the problematic user experience of mobile interaction with ubiquitous annotations involving physical markers, which typically relies on static displays to explain the context and/or interaction but lacks any in-situ dynamic information to motivate the engagement, support users during their interaction and show a trace in the physical environment after interaction took place.

Reflecting this motivation, the early prototype development focuses in particular on mobile interaction with SOLs, rather than direct interaction on the situated display or hybrid models affording multiple alternative ways to interact with a SOL.

Only after the first evaluation in an authentic gallery environment (see 8.3), where visitors were observed to touch the SOL screen to see if it was interactive, did the initial focus on mobile interaction widen in subsequent prototypes (v.6-7) to a hybrid model that additionally supports direct interaction on the SOL display (see 8.4 and 8.5). Of particular interest in this context is how mobile and direct interaction relate to each other and how functionality should be distributed between these interaction modes.

From a methodological perspective, early iterations focus more on technical aspects and use informal approaches to data collection and analysis to inform subsequent designs, while later iterations increasingly focus on more systematic evaluations and ecological validity of results.
8.2 Early prototyping

8.2.1 Prototype 1

Figure 24: Prototype 1 (a) and related mobile applications for visitors (b, c) and administrators (d)

SOL v.1 was a proof of concept prototype consisting of a display application, mobile web applications for visitors to add and browse comments and for administrators to set up objects for annotation, and a server backend consisting of a database and scripts to service the display and mobile applications. The functionality is limited at this stage, however, the prototype supports the complete round-trip for both users and administrators:
• User can connect their mobile device to the display via a QR code or NFC tag, browse annotations for the related object on their device screen, submit their own comment and see the SOL display ticking up in near real-time.

• Administrators can use the mobile admin application to create digital IDs, add digital resources such as an image and description, and edit technical settings such as the poll frequency or display style. Administrators can then enter the object ID on the SOL configuration screen and activate the display mode.

The SOL display has no casing at this stage (Figure 24a) and has a basic admin interface to enter an object id and activate the display. The mobile applications, one for visitors (Figure 24b,c) and one for administrators (Figure 24d), are both mobile-optimised web pages that do not require installation and work across a wide range of mobile devices. The server provides a REST26 API to query the number of comments for an object (see Appendix B1 for more images and technical details).

Evaluation

The prototype was not on public display but trialled in an informal lab setting with several students and staff at the University of Brighton to test the technical setup and gather initial informal feedback. During this time, the prototype was under constant development to add functionality, improve the software design and test the efficiency of different networking models (see Appendix C) and configuration parameters with regard to robustness, responsiveness and battery drain.

Findings from the prototype development and informal field trial include:

| FP1: SOLs should support multiple networking models to adjust to different contexts and requirements |
| FP2: SOLs should maintain, and make available, technical logs to support debugging and post-hoc analysis of problems |

8.2.2 Prototype 2

SOL v.2 improved on prototype v.1 in several ways. Most notably, it had a casing to allow for simple mounting in public spaces that would allow limited trials outside a lab setting. The casing consisted of a wooden frame with a transparent acrylic front plate and printed paper bezel, resulting in a 8.5” x 1.5” viewport (Figure 25a). It was open at the back to give access to the display unit, but otherwise hid critical controls (e.g. home and power button) from users when mounted on a wall (Figure 25b). The display application supported pinch-and-zoom gestures to adapt to different screen and viewport sizes and to allow for ad-hoc adjustments to small variations in the internal positioning of the display unit when setting

26 REST is an acronym for Representational State Transfer, a Web service model allowing clients to access and manipulate web resources using a uniform and predefined set of stateless operations.
up the SOL. In addition, the display application supported custom fonts and colours to allow for experimentation with different display styles, e.g. to simulate monochrome and colour LED and LCD screens (see Appendix B2 for more images and technical details).

![Prototype 2 with NFC tag and printed QR code and custom casing](image1)

Figure 25: Prototype 2 with NFC tag and printed QR code and custom casing (a). Trial at a public event at the University of Brighton (b)

**Evaluation**

SOL prototype v.2 was trialled at an inaugural lecture at the University of Brighton to collect feedback from attendees. The event was attended by approximately 120 people, including university staff and visitors. The SOL was installed on a pillar in the hallway where attendees had drinks before and after the lecture (Figure 25b). There was much interest in the SOL with 12 comments submitted over a total exposure time of approximately 2 hours.

There was no formal data collection during the event. Instead, the researcher observed how attendees engaged and interacted with the SOL, had conversations about the purpose and potential applications of SOLs and in some cases demonstrated its use when attendees were unsure how to interact or had no mobile device with QR reader or NFC capabilities. Insights from these observations and conversations were written down directly after the event.

People generally liked the idea of the SOL, even if some had initially no idea what the comments refer to (the only indication was a poster directly above the SOL advertising the inaugural lecture, there was no question or prompt). Some attendees did not realise at first that the SOL works together with a mobile application to browse and create comments.

Not a single attendee the researcher spoke to had previous experience with NFC. Many people did not know where to swipe the mobile device (i.e. they did not recognise the tag) or how to swipe it, often waving the phone at a distance of between 3-8 cm, which was not close enough to trigger a read. Due to their unfamiliarity with this type of interaction, many attendees were insecure about their own performance and gave up after one or two
attempts. However, after being shown how to use NFC with a mobile device, almost all of them were able to repeat the interaction without problems.

By contrast, several attendees were observed to independently scan the QR code. Even though the interaction is slow and cumbersome, the QR code was well recognised and the interaction worked reliably in all observed instances.

Several technical and interaction problems were observed, including unreliable network connections for both SOL and mobile devices, the mobile Web application not playing well with on-screen keyboards and user generally having difficulties with small keyboards on mobile screens. Furthermore, several people were observed to re-scan the NFC tag when already in browse mode, presumably in an effort to refresh the list of comments on the device screen. The same behaviour was observed in some cases after users submitted a comment and in response were shown a confirmation screen in the prototype v.2 mobile application. Attendees tended to ignore this confirmation screen and instead wanted to see their submission in the list of comments shown on their mobile device, after having noticed the display ticking up.

In the absence of any specific mounting options, the display casing was attached to the wall via hook and loop fasteners. While this allowed for quick and easy mounting, it proved a problem after the event, when detaching the fasteners took off parts of the wall paint. The experience emphasised the requirement for mounting options that enable mounting and unmounting of SOLs with minimum impact on the environment.

Findings from the prototype development and informal field trial include:

<table>
<thead>
<tr>
<th>FP3</th>
<th>Casings should prevent users from accessing critical controls on the display unit, such at home or power buttons</th>
</tr>
</thead>
<tbody>
<tr>
<td>FP4</td>
<td>Casings should allow admin staff to easily access the display unit to access critical controls and to swap out the display unit</td>
</tr>
<tr>
<td>FP5</td>
<td>Casings should support ad-hoc deployment by affording easy mounting and unmounting of SOLs</td>
</tr>
<tr>
<td>FP6</td>
<td>SOLs should provide dynamic control over display styles and parameters to adjust to different casings and environments</td>
</tr>
<tr>
<td>FP7</td>
<td>SOLs should support multiple methods to connect a mobile device to cater for users preferences and technical capabilities</td>
</tr>
<tr>
<td>FP8</td>
<td>SOLs should streamline in the interaction and avoid unnecessary confirmation screens after content submission</td>
</tr>
</tbody>
</table>
8.2.3 Prototype 3

![Prototype 3 with cardboard bezel, NFC tag and QR code (a) in a plastic casing affording access to the display unit (b,c) and ad-hoc mounting and unmounting (d)](image)

*Figure 26: Prototype 3 with cardboard bezel, NFC tag and QR code (a) in a plastic casing affording access to the display unit (b,c) and ad-hoc mounting and unmounting (d)*

The main improvements in SOL v.3 concerned its portability and support for ad-hoc deployments, by using a much smaller display unit and lighter casing that could be easily mounted on most surfaces, and by supporting 3G connectivity, which made it possible to deploy the prototype in environments without or with unreliable WiFi connectivity.

The casing consisted of a flat plastic container with a transparent acrylic front plate and a printed paper bezel, resulting in a much smaller 3.5" x 0.5" viewport (Figure 26a). The front plate was hinged and could be opened while the SOL was mounted to give access to the display unit, which was fixed inside the casing with hook and loop fasteners that allowed some play for adjustments (Figure 26b, c).

The display application and configuration screen, mobile application for visitors and administrators, and the backend were all based on the previous version with minor improvements and bug fixes. These included, for instance, removing the confirmation screen in the mobile visitor application after content submission and adjusting to higher network latencies when the display was connected via 3G networks (see Appendix B3 for more images and technical details).
Evaluation

SOL prototype v.3 was presented at a research seminar at the University of Portsmouth’ School of Computing and at the International Workshop on Visitor-Generated Content in Heritage Institutions hosted by the University of Leicester's School of Museum Studies.

The research seminar at the University of Portsmouth was attended by approx. 25 staff and masters students. It included a 40 min presentation followed by a 20 min hands-on demo. The reaction to the concept and prototype was generally very positive, with valuable feedback regarding alternative content types and social media integration. People mostly used their own mobile device. No interaction problems were observed, however, given the highly technology-literate audience this cannot be considered representative.

The International Workshop on Visitor-Generated Content in Heritage Institutions took place over two days and was attended by approx. 40 participants from museums and research institutions with an interest in user-generated content and technology in museums. It involved a formal paper presentation and two poster/demo sessions, where interested parties were given a short demo of the prototype and had an opportunity to browse and submit comments.

The reaction to the SOL concept and prototype was generally positive at both events. While some participants pointed out that it would work only for people carrying a mobile phone and knowing how to scan the marker, others were enthusiastic about the idea and proposed various deployment scenarios (e.g. festivals; urban environments; university campus) speculating about its uptake and usefulness.

Many people were interested in NFC as a technology but never had tried it out and were unsure whether their phone supported it or how to activate it. Many first-time scans failed because the phone was not held close enough to the tag. Despite these problems, they liked the smoothness of NFC interaction. By contrast, QR codes were more familiar to participants but not very popular, particularly among museum professionals.

An interesting observation at the workshop in Leicester was that some participants were initially unsure about the nature and purpose of the SOL, despite this being explained on the poster next to it. In particular, they were unsure whether the display was operational / interactive and whether they could try it out, indicating that the experimental casing and unfinished presentation of the prototype were not suited for field trials involving unaccompanied use.

One particularly useful insight emerged from discussions with participants from Tate Modern concerning the possibility of exploring SOLs in a learning and interpretation context. The participants pointed out that the current display design with red-on-black characters resembling a LED screen would be out of place in a gallery environment and that something less conspicuous such as e-ink displays would be more appropriate. This insight, later supported by interviews with other museum professionals (Chapter 7), was a key reason to switch to e-ink displays in subsequent prototypes. Another important reason was...
the extended battery life of e-ink displays, which allows for several days of operation without access to mains power and therefore drastically widens deployment options.

Other observations at both events include that WiFi connections, in particular when relying on guest logins, can be extremely unreliable, vindicating the design decision to additionally support 3G mobile connections, and that participants generally appreciated not having to install an app on their mobile device to try out the prototype, vindicating the design decision to implement the mobile visitor interface as a Web application.

Findings from the prototype development and from discussions with participants at both events include:

<table>
<thead>
<tr>
<th>FP</th>
<th>SOLs should be unobtrusive and blend into the gallery environment</th>
</tr>
</thead>
<tbody>
<tr>
<td>FP10</td>
<td>SOLs should look polished and professional to instil confidence in their interactivity</td>
</tr>
<tr>
<td>FP11</td>
<td>SOLs should support multiple networking technologies, including WiFi and 3G</td>
</tr>
<tr>
<td>FP12</td>
<td>SOLs should not require visitors to install a mobile application in order to use them</td>
</tr>
</tbody>
</table>

### 8.2.4 Prototype 4

SOL v.4 was the first high-fidelity prototype in the iterative development process and had major changes and improvements over previous versions. Most notably it uses an e-ink display unit. Reflecting this change, the display application and configuration interface were completely re-written for better control over presentation and interaction aspects, including rendering optimisations to address the high latency of the e-ink screen.

Instead of simply supporting different fonts and styles, prototype v.4 uses a range of configurable screen designs with certain features and functionality, such as a landscape or portrait mode, comments (Figure 27a) and star ratings (Figure 27b) and displaying a question or an image. The casing was laser-cut from medium-density fibreboard, and supports secure mounting on the back plate while the front plate can be removed to swap out the display unit after installation (Figure 27c).

The backend offers support for multiple host organisations and exhibitions, comment moderation, star ratings and RSS syndication while the admin app provides better support for creating digital resources and linking them to object IDs (Figure 27d) and the visitor app now supports star ratings (Figure 27e) in addition to comments (Figure 27f, g).

See Appendix B3 for more images and technical details.
Figure 27: Prototype 4 supporting comments and star ratings (a, b), with MDF casing (c), and updated mobile Web applications for administrators (d) and visitors (e, f, g).

**Evaluation**

The prototype was demoed at four international conferences and workshops, including:

- 2013 ACM International Joint Conference on Pervasive and Ubiquitous Computing (UbiComp 2013)
- 2013 UK Museums on the Web Conference: Power to the people (UKMW13)
- PD-Apps workshop at the 2014 IEEE International Conference on Pervasive Computing and Communications (PerCom 2014)
- International Symposium on Pervasive Displays (PerDis 2014)

Findings from these demo sessions, each of which involved at least one working prototype and presented opportunities for attendees to interact with SOLs in both guided and unguided conditions, are based on observations and discussions with participants, who typically had an academic or professional ubicomp, HCI or museum background.

One common observation across all events was that the conference WiFi network could not cope with the large number of attendees and was extremely slow and unreliable with frequent disconnects. This posed a problem for participants trying to browse or post comments on their mobile device as well as for SOL prototypes when trying to read information from the server, e.g. to update the display after content submission. While the problem seemed less pronounced on mobiles, some of which were using 3G networks (although this option was not available to some international attendees, in particular from...
overseas), it severely affected the update latency on the SOL prototypes resulting in a poor user experience where participants were unsure if their comment submission was successful or not. Exacerbating the problem, unsuccessful update attempts via WiFi in some cases exposed a bug in the display software resulting in heavy screen flicker and an incorrect comment count, further undermining the perception of a working prototype.

<table>
<thead>
<tr>
<th>FP13</th>
<th>SOLs should automatically try to reconnect when a WiFi connection is dropped</th>
</tr>
</thead>
<tbody>
<tr>
<td>FP15</td>
<td>SOLs should have an indicator for network status and signal strength</td>
</tr>
<tr>
<td>FP14</td>
<td>SOLs should avoid at all costs looking &quot;broken&quot;, e.g. showing software glitches or error messages</td>
</tr>
</tbody>
</table>

In unguided situations, where attendees encountered the SOL prototype without having previously seen a presentation, read a poster or listened to the researcher explaining the SOL interaction, some participants were observed to touch the display screen to see if there was a reaction, suggesting that a QR code, NFC tag and dynamic metadata (e.g. current number of comments) is not enough for some people to advertise interactivity and explain the interaction. Related to this problem is feedback from pervasive displays researchers, who pointed out that metadata on its own might not be enough to explain the purpose of SOLs or motivate engagement and suggested that showing actual comments might be more effective in this respect.

| FP15 | SOLs should display suitable information to advertise their interactivity, explain the interaction and encourage engagement |

In addition to the findings discussed above, the observations and discussions around SOL prototypes yielded many other, smaller insights informing the development and suggesting possible future avenues of research.

Two particular areas of interest across all events concerned the use of e-ink displays and possible applications for SOLs. With regard to e-ink displays, many participants were interested in their low energy consumption and outdoor readability, sometimes pointing out the current dearth of applications beyond e-readers and the lack of usability research into their specific qualities. There was considerable interest in this context in technical details of using e-readers as a prototyping platform, in their use as small, cheap, easy-to-deploy displays and in timeframes and potential unit costs for bringing SOLs to market. With regard to possible application domains for SOLs, several participants suggested their use in marketing and civic engagement, and pointed out their commercial potential.
8.2.5 Limitations

Much of the early prototype development focused on engineering aspects in an effort to arrive at a reliable, fully featured, functional SOL version fit for deployment and evaluation in authentic gallery environments. Co-design and evaluation aspects received less attention at this stage, resulting in limitations to the validity and generalisability of its findings.

With regard building functional prototypes, learning was often pragmatic and implicit, drawing on previous software engineering experience and evaluating technical options in an ad-hoc, goal-oriented manner. For instance, the update latency and battery drain of different networking models were measured and documented only with a view to choose preferred options for the involved platforms rather than to produce general insights, expediting the development process but resulting in low external validity.

With regard to the user experience of SOL prototypes, an effort was made to write down observations, feedback and insights from discussions after each event, however, this data is only qualitative and was not formally analysed beyond reflecting on its design implications. Furthermore, the prototypes were trialled, demoed and presented in lab and university environments, conferences and workshops rather than in realistic gallery environments, and mostly involved specialist audiences and domain experts rather than museum visitors, resulting in low ecological validity.

An unintended consequence of the development-oriented nature of these early iterations, whose main goal was to arrive at a robust, fully functional, high-fidelity prototype fit for deployment in authentic gallery settings, was that it did not adequately question deeper-seated design decisions, such as the focus on mobile interaction, despite isolated pieces of evidence suggesting problems with regard to engagement and inclusiveness.

8.2.6 Conclusions

This section has reported on the early prototype development and how it influenced the design of SOLs. It has described the specifications, functionality and informal evaluation of four early prototypes, ranging from low-fidelity designs using various display units and experimental casings to a first high-fidelity prototype involving an e-ink display and purpose-built casing.

Findings in this section are based on software engineering activities as well as informal evaluations in lab, university and conference settings. They relate to the configuration and customisation of SOLs (FP1, FP6, FP11), their deployment and maintenance (FP2-5, FP9-10, FP13-15) and the need for designs to encourage and support engagement (FP7-8, FP12, FP15).

Similar to previous chapters, they range from specific (e.g. FP13: SOLs should automatically try to reconnect when a WiFi connection is dropped) to general (e.g. FP9: SOLs should be unobtrusive and blend into the gallery environment). While all of these findings were useful in informing subsequent prototypes, specific insights were typically acted upon directly in the next design iteration while general insights had more lasting effects on the design.
process, such as e-ink displays to make SOLs blend in with gallery environments and experimenting with different kinds and representations of information over several iterations to investigate how they support engagement and interaction (see following sections in this chapter).

Demoing and informally evaluating SOL prototypes in unstructured settings without control over the environment, the participants and the exact conditions of use had both advantages and disadvantages. On the one hand, the lack of control and messiness of live situations led to many unforeseen problems, including connectivity issues that rendered prototypes non-functional at times, software glitches that could not be addressed on the spot, mounting problems that required ad-hoc consultation with caretakers and sporadic ebbs and surges in the flow of people resulting in periods of idleness and stress with too little or too much information to take in when observing or conversing with participants. On the other hand, these problems provided an indication of issues to expect in real deployments and increased the ecological validity of findings, informing design aspects related to plasticity, ease of engagement and robustness with insights that would be difficult to tease out in controlled lab studies.
8.3 Field trial 1: Fail Better

8.3.1 Introduction

A first empirical evaluation of SOLs in an authentic environment was carried out at Science Gallery Dublin\textsuperscript{27} (SGD), a "new type of venue where today's white-hot scientific issues are thrashed out and you can have your say" (SGD, 2016). SGD cultivates a vibrant and participatory atmosphere and targets young visitors between 18 and 35 years with exhibitions "where art and science collide" (ibid).

The evaluation was carried out during Fail Better, "a free exhibition of beautiful, heroic and instructive failures" (ibid) that aimed to open up a public conversation about failure as an essential part of human endeavour and learning. The exhibition ran for 12 weeks (7 Feb to 27 Apr 2014) and attracted 92,000 visitors during that time. Two SOLs (Figure 28) based on prototype 5 (see Appendix B5) were installed during the final two weeks of the exhibition.

The following sections discuss the particular gallery deployment of the two SOLs, describe the methodology of the study and report on findings and related design implications.

8.3.2 Gallery deployment

Drawing on the idea of social objects (Engeström, 2005; Simon, 2010), the prototypes were attached to exhibits that were likely to provoke a reaction from visitors. One display (SOL1) was installed in the ground floor gallery next to Superman’s Wheelchair (Figure 29) and a second display (SOL2) was installed on the first floor next to the Apparatus for Facilitating the Birth of a Child by Centrifugal Force (Figure 30). Both exhibits were key pieces of the exhibition and attracted much interest from visitors.

\textsuperscript{27} Science Gallery Dublin, https://dublin.sciencegallery.com/
Figure 29: SOL (circled red) installed next to exhibit Superman's Wheelchair in ground-floor gallery.

Figure 30: SOL (circled red) installed next to exhibit Apparatus for Facilitating the Birth of a Child by Centrifugal Force in first-floor gallery
8.3.2.1 Placement

![Figure 31: SOL1 installed next to object label (a) and SOL2 installed below object label (b)](image)

In accordance with Kules et al. (2004), who suggest that interactive installations should be situated in locations with a sustained flow of people and sufficient space for interaction, both exhibits had enough space for visitors to walk around them and to approach the SOL. Considering that displays installed at eye height and close to other eye-catching objects receive more attention (Huang, Koster and Borchers, 2008), SOL1 was installed at eye height next to the object label (Figure 31a) while SOL2 was installed close to eye height just below the object label (Figure 31b). Both displays were easy to read and scan, taking into account that the height of physical markers directly impacts on the success and ease of interaction (Hardy et al., 2010a).

8.3.2.2 Framing

Giannachi and Tolmie (2012) suggest that commenting mechanisms in museums involving novel technologies such as QR codes need suitable framing in order to give visitors a clear reason why to scan the code and why to share their thoughts. This advice was not followed for various reasons. Firstly, the recommendation is based on the authors’ experience with static markers, whereas a key idea behind SOLs is that the provision of dynamic data in-situ helps users to understand their purpose and piques their interest to motivate engagement. Secondly, exhibitions at SGD are highly participative with many different engagement options, which are usually self-explanatory and don’t require extra instructions explaining their use or framing their purpose. Thirdly, we wanted to find out if visitors would notice and interact with SOLs based on their perceived qualities, without explicitly being made aware of them. Finally, SGD staff were confident that visitors would be inquisitive and tech-savvy enough to try out the installed SOLs, when asked about this aspect in interviews before the deployment (see 7.3.6). Consequently, no notices, instructions or calls to action were provided in the gallery space to explain the purpose or use of SOLs.
8.3.2.3 Technical integration

In parallel to the free public WiFi offered by SGD to visitors, SOLs were connected to a separate staff network available in the gallery space. Due to variations in the WiFi signal strength, SOL1 on the ground floor had a very solid connection while SOL2 on the first floor sometimes had connection problems, e.g. when re-connecting after having been charged.

While it was initially planned to run SOLs on mains power to reduce maintenance, the actual deployment was battery operated and depended on gallery staff to periodically check and recharge the displays. Once flat, SOLs were taken from their casing, charged for 3 hours and then re-inserted into the casing, which occasionally left an empty casing in the exhibition space for several hours.

8.3.2.4 Information environment

Brewer (2004) introduces the notion of an information environment as a way to describe how the information shown by an ambient display integrates with other information available at the site. While the evaluated SOL prototype is capable of displaying information about the exhibit it is attached to, such as a short description or image, the installed units were configured to only show the number of comments for an exhibit, a QR code and an URL for visitors to connect their mobile phone (in addition to the NFC tag integrated into the casing). Consequently, there was no information overlap with object labels or with any other information available in the gallery space.

8.3.2.5 Interaction environment

A standard feature in all exhibitions at SGD are student mediators with knowledge of the relevant subject area, ready to answer questions about exhibits and involve visitors into discussions about related issues. Another common feature are opportunities for visitors to get involved in research studies by taking part in a short experiment or filling in a questionnaire. For instance, visitors to Fail Better had the opportunity to take part in an experiment run by the School of Psychology at Trinity College Dublin, which examined attitudes to failure and their impact on wellbeing.

In addition to these moderated engagement opportunities, where visitors could discuss exhibits and related issues with a student-mediator, Fail Better had various interactive installations that invited people to contribute their views and explore additional information.

A Twitter printer (Figure 32) was installed in the ground floor exhibition space. Consisting of a small thermal transfer printer connected via Bluetooth to a hidden computer, the device uses the Twitter API to periodically search for Tweets containing the exhibition hashtag (#failbetter) and then prints them out. The resulting endless print roll spools down from the printer and is collected in a box on the floor below the printer.
A *Fail Wall* (Figure 33) was installed in the first-floor gallery space. The installation prompted visitors to write a personal failure on a plastic tile, photograph it for upload to an online photo stream and then put up the physical tile on the wall for other visitors to read. The installation involved a work area for writing on the plastic tiles, a camera area where the plastic tiles could be photographed and a display area where tiles could be put up on simple shelves. A separate second display area was used to feature a *Fail of the Day* selected and put up by gallery staff.
Some exhibits had associated projections or touch screens that offered additional information videos. For instance, *Superman’s Wheelchair* had a 10 inch touch screen installed in front of the exhibit showing a selection of related video footage (Figure 34).

Together, these engagement opportunities offered analogue and digital routes to participation, spanning a wide range of modalities, capabilities and learning styles. Rounding off the open and participatory atmosphere, SGD offers free wireless internet access to visitors and has no restrictions on mobile phone use in the gallery space, enabling visitors to take pictures of exhibits and share their experience live on social networks.

### 8.3.3 Methodology

The formative evaluation focused primarily on qualitative aspects such as visitors’ awareness and mental models of SOLs. It involved observations and structured interviews with visitors carried out in the gallery space as well as informal interviews with staff about their experience with SOLs and their preferences and requirements for future deployments.

Given the formative and qualitative character of the evaluation, the visitor interviews used convenience sampling, including gallery visitors most easily observed and willing to take part in an interview, which helped to maximise response rates during the limited time available. In order to minimise potential biases in the study and maximise the range of views and insights, the (non-probabilistic) sampling still employed basic strategies from probability sampling. With respect to coverage, the study was carried out over a Friday (workday) and Saturday (weekend), which are likely to vary in audience volume and
composition. With respect to visitor sampling, the researcher aimed for a balanced demographic and included people visiting on their own and in pairs or groups.

8.3.3.1 Visitor observations

Observations were carried out in the gallery space to find out whether visitors notice SOLs and how they interact with them. In order to not disturb visitors’ natural behaviour, observations were carried out without prior notice or informed consent. The researcher’s conduct during these observations was informed by the British Psychological Society’s code of ethics and conduct, restricting observations "[...] to those situations in which persons being studied would reasonably expect to be observed by strangers, with reference to local cultural values and to the privacy of persons who, even while in a public space, may believe they are unobserved." (British Psychological Society, 2011, p.13).

During the observations, the researcher positioned himself at one side of the exhibition space perpendicular to a visitor’s view on the SOL in order to be able to estimate gaze direction and observe any interaction. Observations were carried out for both SOL1 (Superman’s Wheelchair) and SOL2 (Apparatus for Facilitating the Birth of a Child by Centrifugal Force).

Observations focused on "encounters" as a quantifiable unit. Encounters were conceptualised as situations where visitors had a clear chance to notice and engage with a SOL. As a minimum, an encounter involves a visitor approaching and stopping at an exhibit. Visitors might then look at the exhibit, read the object label, look at the SOL, point others to the SOL or engage with the SOL in various ways. Observations were coded on the spot using a coding template supporting both quantitative and qualitative observations.

8.3.3.2 Visitor interviews

In addition to observations, which focused on visitors’ awareness and interaction, structured interviews were carried out to understand visitors’ mental models of SOLs and explore their motivations and barriers to engagement. The interviews also included questions to further qualify recorded observations.

Visitors were approached by the researcher after their encounter with the exhibit and possibly the SOL. Visitors were informed about the research context and asked to sign a consent form before the interview. Interviews lasted between 5-7 minutes and followed a fixed structure. The interviewer recorded answers in a coding template. A short section with demographic questions was filled in by participants themselves after the interview.

8.3.3.3 Staff interviews

In addition to structured visitor interviews focusing on the service-user experience of SOLs, informal interviews were carried out with two members of SGD staff to better understand the service-provider experience of SOLs. Participants included the technical manager at SGD with regard to the deployment and maintenance of SOLs in the gallery over a period of
two weeks, and a curator at the gallery with respect to the fit with engagement strategies
and learning goals in the exhibition.

The interviews with the technical manager lasted 20 minutes and the interview with the
curator lasted 45 minutes. During both interviews, the researcher took notes, which were
revised and complemented immediately afterwards. Due to the low numbers, no formal
data analysis was carried out but key points were derived directly from the revised notes.

8.3.4 Findings

8.3.4.1 Attention and interaction

The observations were carried out over two days during the last week of the exhibition.
Total observation time was 6 hours and 35 minutes, during which 212 encounters were
observed. Of these, 90 involved Superman's Wheelchair and 122 the Apparatus for
Facilitating the Birth of a Child by Centrifugal Force. The observations suggest that 62 (29%)
visitors were on their own, 82 (39%) part of a couple and 68 (32%) part of a group of three
or more.

In the observed 212 encounters, 202 visitors (95%) looked at the exhibit (some only read
the label), 181 visitors (85%) read part or all of the object label and 35 visitors (17%) looked
at the SOL (Figure 35a).

Of the 35 visitors who looked the SOL, six (17%) touched the NFC tag in a manner one
would press a button, four (11%) speculatively touched the screen to see if it was
interactive, three (9%) scanned the QR code and two (3%) scanned the NFC tag with their
mobile phone (Figure 35b).

The observations suggest that of the 35 visitors who visibly noticed the SOL, many assumed
that it was somehow interactive but were not sure how to actually interact with it. At least
ten (28%) assumed a direct interaction model and tried to press the NFC tag or touch the
display screen. When these actions had no effect, visitors did not further investigate but
simply moved on.

Figure 35: Observed visitor attention (a) and interaction (b) with SOLs.

- 177 -
With regard to group dynamics, two out of the three observed QR code scans were carried out by visitors who were part of a couple or group. In both cases the primary actor tried to get their partner or other group members involved, either by pointing out the SOL to them or by sharing their mobile screen after scanning to read submitted comments. In none of the observed interactions did visitors actually contribute a comment.

### 8.3.4.2 Visitor perspective on SOLs

A total of 17 visitor interviews were carried out, involving ten female (59%) and seven male (41%) participants. The age range of interviewees reflects SGD's target audience with ten participants between 25-34 years of age (59%), three between 18-24 years (18%) and others falling in equal measure into older age brackets (Figure 36a).

All participants reported owning a smartphone, defined as a mobile phone with touch screen and web capabilities, with only one having no data plan and relying on WiFi (Figure 36b). Eight interviewees (47%) reported having a barcode scanner installed on their phone and nine (53%) stated that they had scanned a QR code before. This contrasts with only two interviewees (12%) reporting having a smartphone with NFC capabilities and none (0%) ever having scanned an NFC tag.

When asked whether they had noticed the SOL, referred to as “the small display next to the object label” and pointed out by the interviewer, nine visitors (53%) answered yes and eight visitors (47%) answered no (Figure 37a).

With regard to visitors' understanding of the purpose of SOLs, 14 visitors (82%) thought they were for reading comments, 12 visitors (71%) thought they would also allow submitting comments and three visitors (18%) were not sure (Figure 37b). This suggests that the majority of visitors made correct assumptions about the purpose of SOLs in the gallery space once they were aware of them.
When asked about interactivity, 14 respondents (82%) thought that SOLs were interactive in some way, while one visitor (6%) thought they were not interactive and two visitors (12%) were not sure (Figure 38a). Asked how the interaction with SOLs might work, 13 visitors (76%) answered that one would scan the QR code, two visitors (12%) thought it was a touch screen and another two visitors (12%) were not sure (Figure 38b). Contrary to observations, which suggest that many visitors assumed a direct interaction model, the interviews indicate that most visitors understood that scanning the QR code was the primary mode of interaction.

When asked what kind of content they would expect when scanning the SOL, eight visitors (47%) answered they would expect to be directed to the gallery's website where they could read and submit comments, six visitors (35%) would expect a list of comments and three visitors (18%) answered they would expect “information” but did not further specify what kind of information (Figure 39a).
Finally, when asked what it would take for them to engage with the SOL and what was holding them back, six visitors (35%) mentioned a lack of interest in comments or more generally in further engaging with the exhibit, four visitors (24%) mentioned technological barriers such as not having a QR code scanner installed on their phone or not being sure exactly how to scan a code, two visitors (12%) mentioned a lack of information in the gallery that would explain the purpose and use of SOLs and five visitors (29%) did not answer the question (Figure 39b).

8.3.4.3 Museum perspective on SOLs

To understand the experience of gallery staff in setting up and maintaining SOLs and explore the factors playing into possible future deployments, two interviews were carried out with a technical manager (TM) and curator (CU) at SGD.

TM’s feedback on the experience of setting up and maintaining SOLs in the gallery over a period of two weeks included:

- TM had no problems connecting and setting up the SOLs and found the admin interface clear and easy to understand.
- TM pointed out that due to a design error putting the power supply opening on the wrong side of the casing SOLs were battery operated and charged when needed.
- TM had not experienced any connection problems with SOLs and never noticed the small "disconnect" icon in the top left corner of the screen. TM pointed out that even if he had noticed the icon he would not have known what it means.
- TM found SOLs to be low maintenance and would use them again.

Overall, the interview with TM suggests that SOLs are easy to set up and maintain but that admin functionality could be further improved. Firstly, the status indicator for connectivity is not self-explanatory and currently not documented for administrators. Secondly, when battery operated SOLs depend on gallery staff to notice when they run out of battery, leading to periods of unavailability while charging.

CU’s deliberations on a possible future deployment of SOLs in another exhibition included:
• CU pointed out that QR codes were cryptic and associated with advertisement, wondering whether they were "beyond repair" with regard to the user experience.

• CU enquired whether mobile phones and QR codes were the only way to interact with SOLs or if they offered alternative ways of interaction, indicating that she would prefer an option to directly interact with the SOL display via touch screen or buttons.

• CU raised the issue of content quality, questioning the value of overly simple and spam comments and asking how comment quality could be improved.

The main discussion points in the interview with CU were the poor reputation of QR codes and the fact that interaction with the current SOL prototype necessarily requires a mobile device, which is less direct and excludes visitors without smartphones. On a more general level, the interview made clear that the quality of submitted content and the options to integrate them into a wider media strategy are important aspects for curators when considering a commenting platform.

8.3.5 Discussion

The findings have a number of design implications for the next iteration of SOLs and can inform future field trials. This section discusses specific problems and possible ways to address them. It is structured after the three main components of the platform including the SOL display, the mobile app for browsing and creating comments and the admin interface supporting the maintenance of SOLs.

8.3.5.1 Design implications for SOLs

There is an inherent design tension in SOLs between being peripheral to not distract from the exhibit but at the same time noticeable enough to encourage engagement. With observations suggesting that only 17% of visitors are aware of SOLs and self-reported awareness at 53%, the current SOL design is clearly not too obtrusive or distracting. On the contrary, these numbers suggest that SOLs could be more conspicuous to reach higher levels of awareness without diverting too much attention from the exhibits.

The strong discrepancy between observed and self-reported awareness is remarkable. While some of this difference might be attributed to the Hawthorn Effect (Turnock and Gibson, 2001) or "good bunny effect" (Robson, 2002), where respondents try to give "the right" answer to a researcher's questions, another possible interpretation is that visitors automatically blank out QR codes when they see them, resulting in only a passing glance that is difficult to detect in observations. People's low expectations of QR codes are well documented (e.g. Russel, 2011; Aguirre, Johnston and Kohn, 2012), and ignoring them in this manner would be consistent with the documented phenomena of "banner blindness" (Benway, 1998), where people learned to automatically blank out advertising banners on the Web as they are of no interest to them, and "display blindness" (Mueller et al., 2009), where people do not notice displays in their environment anymore due to low expectations about their content based on prior experiences.
This interpretation is further supported by the low numbers of actual scans, and by visitor interviews suggesting a weary and sometimes negative attitude towards QR codes. While most visitors understood that they were supposed to scan the QR code on the SOL with their mobile phone, they had no clear expectations what to expect in return. Many visitors reported that a lack of interest in the expected content was their main barrier to engagement. This suggests that the dynamic information provided by the evaluated SOL prototype (i.e. the number of comments) is not enough to give visitors a clear idea about the content they can expect and motivate engagement.

Possible ways to address these problems include de-emphasising the QR code in the user interface and providing more detailed information on the display. Current practice in museums (and elsewhere) is to use QR codes not only in their technical capacity as an optical marker to be scanned by mobile devices, but also as a means to advertise interaction opportunities to potential audiences. While the former is a robust, cheap and relatively well-known mechanism, the latter has come into disrepute due to the low quality of content often linked to. Displaying QR codes less prominently or relegating them to a secondary screen together with other connection options helps to split these two roles and make use of their qualities as robust and well-supported machine-readable markers while not misusing them to advertise interactivity to potential audiences. At the same time, users’ lack of interest in the expected content can possibly be addressed by providing more engaging information on the SOL. One way to achieve this is to “bring the data forward” (Saffer, 2013) and show actual comments on the display that can give visitors a better idea of the potential rewards of engagement.

Another recurring theme in this evaluation is the need to support direct interaction on SOLs without a mobile device. Visitors’ expectations of how to interact with SOLs are shaped by the wider interaction environment and their experience with other interactive installations, which often support hands-on direct interaction in the form of touch screens or buttons. Even though 76% of interviewed visitors correctly identify scanning the QR code as the primary mode of interaction with the evaluated SOL design, observations suggest that visitors also build on their prior experience in the gallery space when trying to figure out how to interact with SOLs, e.g. by tentatively touching the display like a touch screen or trying to press the NFC tag like a button. While from an evaluation perspective these are failed interaction attempts, from a design perspective they present a clear opportunity to provide interaction support at a critical moment in visitors’ engagement with SOLs. Supporting direct interaction is also desirable from a curatorial perspective as it is more inclusive and enables visitors without smartphones and technical skills to participate.

Two common barriers to engagement mentioned in visitor interviews are a lack of information about SOLs and technological issues, such as not having a QR code scanner installed. With regard to the former, the results put into question the notion of SOLs being self-explanatory and the displayed dynamic information being intriguing enough to encourage engagement. Instead, future deployments should heed recommendations in the literature to provide information that frames and explains their purpose and use to visitors.
(Giannachi and Tolmie, 2012). With regard to the latter, the results suggest that it is beneficial to support a wide range of mechanisms to connect a mobile device and thereby minimise the chances of technical issues or preferences becoming real barriers to engagement. In addition to the currently supported NFC tags, QR codes and manual URL input, this could, for instance, involve posting comments on SOLs via commonly used social platforms like Twitter, which at least a subset of visitors are familiar with and have already installed on their mobile device.

### 8.3.5.2 Design implications for the mobile application

As the main interface to browse and create comments, the mobile application has considerable potential to impact on content quality, which is an important aspect for organisations when considering a commenting platform. Content quality also is important from a visitor’s point of view as it determines the potential value they get from engaging with SOLs. This aspect becomes particularly relevant when content quality is judged by visitors themselves. While there are no common quality criteria for content and the concept quickly becomes contentious when quality is judged by representatives of the organisation, self-regulating community-led approaches have proved successful on the Web, where various rating mechanisms enable users to increase or decrease the visibility of content. A rating mechanism integrated into the browsing experience could possibly help to improve content quality in a transparent and democratic way.

### 8.3.5.3 Design implications for the admin interface

While the staff interview suggest that SOLs are easy to deploy and maintain, it also revealed that the status indicators in the current prototype are not self-explanatory and either need to be re-designed or better documented. Additional information in the setup screen could further help to increase awareness of the battery status and connectivity of SOLs. Furthermore, the interview and observations in the gallery indicate that relying on busy gallery staff to notice SOLs running out of battery before recharging them is impractical as it can lead to blank screens and empty cases in the gallery space. SOLs should therefore proactively notify administrators when their battery runs low, e.g. by sending them an email.

### 8.3.6 Reflection on collaboration and research environment

Planning the field trial with SGD staff and carrying out the evaluation in an authentic gallery context had a number of implications that were beyond the researcher’s control. A key issue in this context was the geographical distance between the researcher’s base in Brighton, UK, and SGD in Dublin, IRL, which impacted on communications and limited the time the investigator was physically present at SGD before and during the field trial.

After an initial face-to-face meeting with SGD staff in Dublin, communication about the SOL deployment and evaluation relied on a range of channels including shared online documents, email, telephone and video conferencing, all of which could not fully make up
for the advantages of being physically present in the gallery during the exhibition planning. As a consequence, the investigator had an incomplete understanding of the interaction environment resulting, for instance, in the NFC tag on the SOL prototype looking similar to the push button used in another exhibit in the gallery. Furthermore, a lack of detail in the communication with technical staff led to the SOL casings having the power cord opening on the wrong side, resulting in SOLs having to be run on battery rather than mains power as originally planned and leading to maintenance problems during the field trial.

In order to minimise the costs of the evaluation, which involved travel and accommodation, the researcher allocated only two days for observations and interviews in the gallery, rather than being present and collecting data over the whole period of deployment. While this was not a problem with regard to sample sizes (see 8.3.7), it meant that the maintenance of deployed SOLs fell mainly to busy SGD staff, whose primary concerns are curatorial rather than research-related, while the investigator was absent much of the time and learned of operational problems such as displays running out of battery when not charged overnight (see 8.3.2.3) only post-hoc.

These experiences suggest two classes of problems when evaluating SOLs in a live gallery environment. Environmental problems, such as connectivity issues or lack of mains power, which can be designed for, and higher-level problems arising from physical distance and the different agendas of researcher and museum staff, which easily upend best laid plans and cannot be adequately prepared for. While future field trials should therefore aim to improve communication and allocate more time to be physically present in the gallery, a key insight from this experience is to embrace the messiness of in-the-wild evaluations and accept that they give rise to real-world problems that are difficult to discover in evaluations carried out in a lab environment and without the involvement of a museum partner.

8.3.7 Limitations

Following the recommendation in Alt et al. (2012) to clearly identify whether a study focuses on internal, external or ecological validity, the introduction and detailed description of the gallery deployment firmly place the focus on ecological validity. At the same time, the methodology section explains how the study addresses internal validity, by using coding sheets and interview scripts to ensure consistency in observations and visitor interviews, and external validity, by varying the times and weekdays for observations and interviews to address a wider range of audiences and by aiming for a balanced sample with regard to gender and age. A potential weakness are the low sample sizes for visitor (17) and staff (2) interviews, however, with reference to Nielsen (1994a) and Sauro and Lewis (2012), this is acceptable given the formative character of the study, which aims to identify problems in the evaluated prototype rather than summatively evaluate a design.

With regard to transferability, some findings of this study are equally relevant to other interactive public displays and gallery contexts, even though they are based on a specific SOL prototype and gallery context. Examples include visitors’ tendency to ignore QR codes, referred to as “QR code blindness” in this study and related to “display blindness” and
“banner blindness” reported in other research, the need to integrate with the wider interaction environment in the gallery, for instance by supporting touch screen interaction, and the requirement to provide adequate administration tools for museum staff.

8.3.8 Conclusions

This section has reported findings from a formative evaluation of SOLs in a realistic setting. It has motivated the study with a need to evaluate ubicomp technologies in-situ, discussed the gallery environment at SGD and described the deployment of SOLs in the gallery space. It has then explained the methodology of the study before discussing its findings and their design implications, and reflecting on the collaboration with SGD and the research environment.

The gallery environment at SGD was found to be rich in engagement opportunities, with analogue and digital routes to participation that address a wide range of modalities, capabilities and learning styles. While such an environment primes visitors for engagement it also is very competitive, requiring installations to provide an excellent user experience in order to attract visitors’ attention. It also requires designs to consider interaction modes and mechanisms used in other interactive installations in the gallery as they shape visitors’ expectations in the exhibition.

One of the most noteworthy outcomes of the evaluation is the possible departure from a single-screen model for SOLs, which displays a small amount of metadata and some basic information to initiate interaction via a mobile application but does not support any direct interaction on the display itself. The findings suggest that providing more information and supporting direct interaction on the SOL display might help to increase engagement rates in a gallery context. The interaction environment at SGD primes visitors for direct interaction and many visitors have been observed to touch the SOL. Curators like the idea of direct interaction because it is more inclusive than a model which necessarily requires a mobile phone. As direct interaction enables visitors to manipulate and navigate information, it can be used to show actual content in addition to metadata, which gives users a better idea what content to expect and therefore might encourage further engagement. It can also be used to explain the use of SOLs, which might help visitors to overcome barriers to engagement. Finally, an interface with direct touch interaction can help to de-emphasise QR codes and avoid the effects of QR code blindness as they can be removed from the idle screen and only shown on request when users’ direct interaction indicates an interest to engage further.

Another important outcome is the need for mechanisms to increase content quality. Findings suggest that content quality is an important aspect for curators as quality comments can considerably enrich an exhibition. Content quality is also important for visitors as it directly relates to the value they get out of interacting with a commenting system. A successful mechanism for increasing the relevance and quality of user-generated content on the Web is based on community members rating each other’s content. Such content rating systems are well-researched (e.g. Cosley et al., 2003; Turnbull, 2007; Sparling
and Shilad, 2011) and the companion mobile application for SOLs used to browse and create comments seems a suitable context for visitors to rate comments and thereby collectively control their ranking and visibility.

With regard to the collaboration with SGD and carrying out the field trial in a live gallery environment, several problems indicate that future studies would benefit from better communication and allocating more time for the researcher to be present in the gallery. At the same time, however, these same problems helped to uncover requirements for SOLs that would be difficult to identify without a museum partner or in a controlled lab study, and thereby justified the problematic collaboration and messy research environment.

Overall, the field trial at Fail Better was an instructive failure for the evaluated SOL design, in line with the central theme of the exhibition. However, while engagement with SOLs was disappointing, the evaluation uncovered specific problems in the current prototype, helped to understand them in the context of a realistic environment and resulted in findings to inform the next design iteration of SOLs.
8.4 Formative user-testing and co-design

8.4.1 Introduction
User-testing and co-design sessions were carried out to formatively evaluate the design of SOL prototype 6 (Appendix B6), which incorporates findings from the first field trial (see 8.3) and is the first iteration supporting direct touch screen interaction. The scope of these sessions was to evaluate concrete designs and explore and prioritise design alternatives together with potential users. The goal was to improve usability and learnability by finding out whether the system behaves as expected, uses appropriate terminology and iconography and meets users' needs and preferences.

Involving users in the design process has been repeatedly shown to lead to more relevant and usable information systems (Gould and Lewis, 1985; Baroudi, Olson and Ives, 1986; Spinuzzi, 2005), however, it has also drawn criticism as being expensive, ineffective, encumbered by language problems and hindered by entrenched roles of users and developers (Beath and Orlikowski, 1994; Heinbokel et al., 1996).

Some of these differences in how user involvement in the design process is perceived and valued may derive from the context in which it happens. This view is espoused by Norman and Verganti (2014), who distinguish between incremental and radical innovation in product design and suggest that user involvement well suited for the former but less so for the latter (Norman and Verganti, 2014). Support for this view crops up repeatedly over time in both academia and industry. For instance, Scaife et al. (1997) question the ability of stakeholders to contribute as equal partners in the software design process, Nielsen (1993) points out that "users are not designers" (pp. 12-13) and Steve Jobs, former head of Apple Corporation, famously stated that "it’s not the consumers’ job to figure out what they want" (Berry, 2011). A key argument often mentioned in this context is that users are able to find problems in existing designs but usually lack the technical overview to generate radically new ideas and the design skills to turn them into usable products.

8.4.2 Methodology
Considering the potential benefits and limitations of involving users at this stage of the development process, the formative evaluation and co-design carefully balanced between eliciting feedback on existing designs and enabling participants to contribute new ideas. The sessions involved a working prototype in order to give participants an overall idea of the developed system's purpose, functionality and interaction possibilities. In addition, a number of paper prototypes were used to visualise possible design alternatives and provide a basis for participants to comment on, prioritise and develop their own ideas if they wished.
The user-testing and co-design sessions draw on Nielsen’s (1994b) idea of “guerrilla usability research”, including mock-up scenarios and impromptu participant recruitment. They involved a pop-up usability stall (Figure 40) that was set up at short notice in two public spaces on the university campus, including a sitting area in the Watts Building on Moulsecoomb campus and a public gallery space on Grand Parade campus. The stalls were made up of a trestle table sourced on location, a cardboard mock-up of a gallery scenario, consisting of an exhibit and working SOL prototype for participants to leave comments on (Figure 41a) and a mounted video camera to record user interaction with the prototype. Design materials were provided to support the co-design sessions, such as images illustrating scenarios of use and paper prototypes of design alternatives (Figure 41b), a mobile phone with a pre-installed QR code reader application and NFC support for participants to use in user task as an optional alternative to their own mobile device, information sheets, consent forms and coding sheets supporting note-taking.

In the user-testing part, participants carried out a series of tasks on the SOL prototype. Specifically, they were asked to first read some comments and then add a comment of their own. This was aimed at detecting usability problems in the current design while at the same time familiarising participants with the basic idea and functionality of SOLs so that they were better equipped to make informed contributions in the subsequent co-design activity.
Figure 41: Mocked-up a gallery scenario for participants to comment on an exhibit using a SOL (a) and paper prototypes used in the co-design activity (b).

Following Nielsen's (1994b) simplified speak-out-loud protocol, participants were asked to verbalise their thoughts while completing the task and only given further instructions if they got stuck. A brief discussion after the task explored users’ general thoughts about the system and any problems they found. The interaction and concluding discussion were video recorded for later analysis of how users understand and interact with the system.

In the co-design activity, participants were presented with paper prototypes of whole screens and of specific interface details illustrating design alternatives. The researcher followed a script with specific questions exploring participants’ preferences concerning information architecture, information representation and terminology based on concrete examples. Participants could then indicate their preferences among the presented designs or describe alternative designs and optionally draw them on paper. Participants’ preferences and ideas were recorded on a task-specific coding sheet allowing for efficient note taking and thereby minimising the impact on task facilitation.

Wrapping up the session, participants were asked to fill in a short demographics form and optionally to complete two standard questionnaires. These included the System Usability Scale (SUS) described in Brooke (1996) to assess the usability of the current prototype, and Ogertschnig and v.d. Heijden’s (2004) short form of the Hedonic value and Utility (HED-UT) scale developed by v.d. Heijden and Sørensen (2002) to measure the hedonic qualities and the utility of mobile information services (both available in Appendix F).

Participant recruitment involved the researcher approaching passers-by and asking if they would like to take part in a research study. Prospective participants were then given an overview of the research and what the study involved, before being asked to sign a consent form. Particular care was taken to point out that the user-testing part of the session was video recorded but that the camera would only capture their hands and not their face.
Sauro and Lewis (2012) base sample sizes on Problem Discoverability \( p \), i.e. the likelihood of detecting a problem, and Problem Discovery Goal \( \Pr(x \geq 1) \), i.e. the likelihood that a problem is detected by at least one participant during the study. Their recommend sample size for formative studies is expressed as a function of these two variables solved for \( n \): 

\[
\Pr(x \geq 1) = 1 - (1 - p)^n
\]

The sessions aim to inform the research at a relatively coarse level and individual responses reflect to some degree personal preferences and skills of participants. Based on this consideration, the study assumes a relatively low Problem Discoverability of .15 (i.e. 15% chance of a problem being discovered by at least one participant).

Given that the study does not involve a fully developed design but variations of partial designs, an overly ambitious Problem Discovery Goal would be pointless. The study therefore sets an achievable Problem Discovery Goal of .85 (i.e. at least 85% of current usability problems should be discovered in study as a whole). Based on these parameters, Sauro and Lewis' (ibid) formula suggests a sample size of at least 12 participants. The study involved a total of 16 participants (\( n=16 \)).

![Figure 42: Participants' age (a), first language (b), gender (c) and frequency of visiting museums (d).](image)

Participants were recruited among staff and students at the University of Brighton, in particular from the College of Life, Health and Physical Sciences located at Moulsecoomb campus, and the College of Arts and Humanities at Grand Parade campus. While there is no need in these sessions for a statistically representative sample, the study aimed to reduce
bias by including participants from a range of age groups and cultural backgrounds and balancing the number of males and females (Figure 42a,b,c).

With regard to participants' interest and familiarity with museums, 10 respondents (63%) reported visiting a museum or gallery 3-4 times per year or more, while 6 respondents (37%) answered they visit 1-2 times or less (Figure 42d). This self-reported frequency of museum visits is higher than the UK average of 17% visiting museums or galleries 3-4 times a year and 32% visiting 1-2 times per year reported for 2013 by the Department of Culture, Media and Sport (DCMS 2013).

Basic profiling shows participants to be new media literate but not overly tech-savvy. 13 participants (81%) reported owning a smartphone, referred to as "a mobile phone with touch screen and internet access" (Figure 43a) and 12 participants (75%) had scanned a QR code before (Figure 43b). With regard to Near Field Communication (NFC), only 3 participants (19%) reported that their smartphone had an NFC reader while 13 participants (81%) said their phone had no NFC reader or were not sure about this aspect (Figure 43c). Nine participants (56%) were Twitter users (Figure 43d), which is considerably higher than the UK average of 19% at the time the study took place (Ofcom, 2015).
8.4.3 Results from user tasks

The user task involved participants first browsing comments on the system and then adding a comment of their own. While it was carried out by all 16 participants, four videos were excluded from the analysis due to technical problems (camera view did not cover all of the interaction area; recording interrupted; low audio quality due to background noise). While this reduces the evaluated sample for the first part of the study to 12 participants (n=12), it still meets Sauro and Lewis' (2012) recommended sample size for the problem discoverability (.15) and overall problem discovery goal (.85) of the study.

Video recordings from the user task were analysed with respect to participants' interaction choices, timings and utterings during the activity and in the subsequent brief discussion. Quantitative aspects such as interaction choices and timings were coded directly from video. Codes for interaction choices were based on a round of preliminary viewings to establish what kind of interactions were reliably observable and of interest (see Table 26). Qualitative aspects of the study are informed by observations and participants' utterances, which were noted/transcribed from video footage and then analysed using Miles and Huberman's (1994) two-step process involving data reduction and data visualisation to identify common themes. The findings and related requirements (Findings from user Testing [FTn]) are discussed in the following sections.

8.4.3.1 Quantitative observations

This section discusses quantitative observations regarding users' interaction with the SOL prototype while completing the set task: first browsing comments on the system and then adding a comment of their own.

<table>
<thead>
<tr>
<th>Idle screen</th>
<th>100% (12 out of 12)</th>
<th>touched the idle screen without any help or prompting to start the user task</th>
</tr>
</thead>
<tbody>
<tr>
<td>Browse screen</td>
<td>92% (11 out of 12)</td>
<td>used the navigation buttons to navigate between comments</td>
</tr>
<tr>
<td></td>
<td>82% (9 out of 11)</td>
<td>first pressed the right (next) navigation button [one participant did not browse comments but only read the first comment and proceeded to add a comment]</td>
</tr>
<tr>
<td></td>
<td>27% (3 out of 11)</td>
<td>used both the left (previous) and right (next) navigation buttons [see above]</td>
</tr>
<tr>
<td></td>
<td>25% (3 out of 12)</td>
<td>tried the close (home) button, none of them after submitting a comment</td>
</tr>
<tr>
<td></td>
<td>92% (11 out of 12)</td>
<td>pressed the add button to add a comment</td>
</tr>
<tr>
<td></td>
<td>50% (6 out of 12)</td>
<td>were so engrossed in browsing comments that they needed a prompt to move on to adding a comment</td>
</tr>
<tr>
<td>Help screen</td>
<td>42% (5 out of 12)</td>
<td>closed the help screen after reading and before adding a comment</td>
</tr>
</tbody>
</table>

- Table 26 continues next page -
Chapter 8 Prototype design and evaluation

<table>
<thead>
<tr>
<th>Physical Mobile Interaction</th>
</tr>
</thead>
<tbody>
<tr>
<td>42% (5 out of 12)</td>
</tr>
<tr>
<td>used their own phone to add a comment</td>
</tr>
<tr>
<td>33% (4 out of 12)</td>
</tr>
<tr>
<td>used the QR code to add a comment</td>
</tr>
<tr>
<td>17% (2 out of 12)</td>
</tr>
<tr>
<td>used the NFC tag to add a comment (both computing staff)</td>
</tr>
<tr>
<td>17% (2 out of 12)</td>
</tr>
<tr>
<td>used manual URL input to add a comment</td>
</tr>
<tr>
<td>8% (1 out of 12)</td>
</tr>
<tr>
<td>used Twitter to add a comment</td>
</tr>
<tr>
<td>42% (5 out of 12)</td>
</tr>
<tr>
<td>visibly noticed the SOL counter ticking up after submitting a comment</td>
</tr>
</tbody>
</table>

Table 26: Qualitative observations of participants’ interactions with the SOL.

The data presented in Table 26 shows that all participants understood that they need to touch the idle screen to start the user task, suggesting that the current design is clear and unambiguous. However, qualitative feedback (see 8.4.3.3) suggests that the current user prompt could still be improved.

Almost all participants (92%) used the navigation buttons to navigate between comments, suggesting that they are easy to spot and to understand. A clear majority of users (82%) started browsing to the right and only some (27%) used the left navigation button at all. While this behaviour might be culture dependent and possibly different in right-to-left or top-to-bottom writing systems, it might still be exploitable in the context of improving perceived content quality, for instance when ordering user-generated comments so that highly rated content is presented first.

The data suggests that the current "Add" button is largely self-explanatory with only 1 out of 12 participants needing a prompt to press it when asked to add a comment - despite many participants in the subsequent co-design session expressing a preference for the more explicit "Add Comment" version of the button (see 8.4.4.3).

The data also suggests that the "Close" button, which returns to the idle screen, might not be needed. Only a minority (25%) of participants used the "Close" button at all. In each case the participant immediately touched the Idle screen again to get back to the Browse screen. Not a single participant used the "Close" button after submitting a comment to bring the display back into the state before it was first used.

**FT1:** Interaction screens should not rely on users to return the SOL to its default idle screen but time-out automatically after a certain period of inactivity.

The fact that only 5 out of 12 participants used the "OK, got it" button to close the Help screen (after reading the help information and before trying to add a comment) exposes a usability problem in the evaluated design: The current help screen shows only a small, mainly symbolic and difficult to scan version of the QR code while at the same time obscuring the larger QR code shown on the Browse screen. This makes it impossible for users to scan the larger QR code while keeping the help screen with instructions open.
Qualitative observations (see 8.4.3.3) show that several participants were not sure where to find the QR code when reading the help screen.

**FT2:** Connection information (e.g. QR code, URL, hashtag) should be available in all screens where user interaction is anticipated, including in help screens explaining the interaction to first-time users.

With regard to connecting a mobile phone to the SOL, results show that participants used all four interaction mechanisms, including QR code scans, manual URL input, NFC scans and posting comments via Twitter. While the sample is not representative and percentages may vary from actual usage of these technologies in the field, the results suggest nonetheless that SOLs should offer as many interaction methods as possible. This is further supported by qualitative comments (see 8.4.3.3) were participants explain their choice of interaction mechanism mainly by excluding other options (e.g. "My phone does not have NFC", "I have no QR code scanner installed", "I am not a Twitter user"), suggesting that the actual choice for specific users is much smaller than what is technically supported by the SOL.

**FT3:** SOLs should provide a wide range of interaction methods and not rely on specific technologies, applications or social network membership.

### 8.4.3.2 Timings

Time data for the user task (Figure 44) shows that participants, all of which were first-time users, needed little time to orient themselves on the Browse screen and were quickly able to browse comments, with a mean time of only 12 seconds (SD = 7.82) between activating the browse screen and hitting the next button (including the time needed to read the first comment). None of the participants showed any hesitation with regard to identifying and operating the navigation buttons, suggesting they are well recognised.

The mean time participants spent browsing comments was 81.5 seconds (SD = 55.72), with individual times varying considerably. These results are, however, distorted by the researcher prompting some participants, who kept reading comments on the Browse screen for a prolonged time, to progress in the user task and add a comment. Without this prompt, 6 out of 12 participants would have taken even longer to read comments, indicating the popularity of the browse feature.
Figure 44: Interaction times (in milliseconds) derived from video recordings showing upper and lower quartile, inter-quartile range and mean (diamond). From left to right: time for participants to orient themselves on the browse screen (time difference between screen activation and first interaction); time to browse comments; time to read the help screen (time difference between screen activation and initiating mobile interaction); time to connect the mobile phone via QR code, NFC or manual URL input (or, alternatively, to start the Twitter app); and time to write and submit a comment.

It took participants on average 42.27 seconds (SD = 21.11) to read the help screen. While this time is inflated by some participants commenting on the help screen as part of the speak-out-loud protocol, it still documents the high information density of this screen and indicates the importance to optimise its information architecture. The time also suggests that users looking for help are prepared to read more detailed information in order to complete their task.

FT4: Help screens should provide detailed information and have a highly optimised information architecture.

The average time between participants starting efforts to connect their mobile phone to the SOL and being presented with the mobile web application on their device screen was 11.63 seconds (SD = 6.85), with a minimum of 1 second (NFC) and a maximum of 24 seconds (manual URL input). These times only include users who were able to complete this step on their own. 4 out of 12 participants were not able to complete this step without help, suggesting that mobile interaction with the SOL is still a major hurdle to participation.
### 8.4.3.3 Qualitative observations

Observations of participants' interactions and their utterances while completing the user task were transcribed and analysed in a two-step emergent coding process, involving first data reduction and then data visualisation to identify common themes, as described in Miles and Huberman (1994). Findings are presented below in Table 27.

| Browse screen | OT1 | Some participants give feedback on usernames and user-generated content together with feedback on the interface and interaction, suggesting that the conceptual boundary between interface (chrome) and content could be made clearer. |
| - | OT2 | Some participants find the connection information at the bottom of the screen confusing and are not clear if it is interactive or not. |
| - | OT3 | Some participants are not sure about the purpose of the Add button. |
| - | OT4 | Some participants explicitly note the QR code, hashtag and Twitter symbol. The NFC symbol is never referenced and at least by one participant mistaken for a speaker symbol. |

| Help screen | OT5 | Some participants seem disappointed that comments can only be added via a mobile device. |
| - | OT6 | Some participants are unsure where to find the QR code referenced in the help screen (shown in browse screen - obscured by help screen). |
| - | OT7 | Some participants are not sure about the NFC tag and symbol, with one assuming it represents speaker or voice recording functionality activated by pressing the tag. |
| - | OT8 | Some participants have no problems recognising the different interaction options. |

| Physical Mobile Interaction | OT9 | Physical mobile interaction is problematic for various reasons, including lack of experience, lack of necessary hard- or software and lack of connectivity. |
| - | OT10 | Some participants are not sure about the meaning or purpose of the NFC tag. |
| - | OT11 | QR codes and the Twitter symbol are recognised even by participants who don't use them. |

| Mobile App Interaction on the phone | OT12 | Participants have no problems interacting with the mobile app. |
| - | OT13 | Once the interaction between SOL and mobile is clear, participants start wondering about higher-level aspects such as language, word count and time it takes to enter the comment. |
| - | OT14 | Participants show an interest to see their comment on the SOL after submission. |

| General comments after completing the user task | OT15 | Despite pointing out specific problems and potential improvements, many participants state that they find the interface clear and easy to use. |
| - | OT16 | Some participants mention that the e-ink screen is unfamiliar, unresponsive and flickering. |
| - | OT17 | Suggested improvements include making the Add button more explicit, making the QR code available on the Help screen, making the link information interactive and clarifying the symbol and terminology for the NFC tag. |
| - | OT18 | The current NFC tag is misunderstood by some participants as a button, and the NFC symbol is not recognised (and misinterpreted as a consequence). |

*Table 27: Observations of participants' interactions and utterances while completing the user task.*
Based on OT1, it is important to emphasise the difference between chrome and content, i.e. between the actual interface of the system and the content it displays, in order to support users in understanding the interface and forming an appropriate mental model of the overall system.

**FT5:** Provide visual clues that help users to distinguish between the interface and the user-generated content presented in the interface.

Based on OT2, the user interface should clearly identify interactive elements and possibly provide help information when users try to interact with otherwise non-interactive elements.

**FT6:** Provide visual clues that help users to recognise interactive elements.

**FT7:** Show supporting information when users touch screen elements that are not interactive.

Based on OT3, the primary interaction element should be labelled unambiguously and easy to understand for first-time users.

**FT8:** Clearly label the primary interaction element.

Based on OT4, OT7, OT10, OT18 the user interface should only use well-known and commonly used graphic symbols, especially if they are not accompanied by a text label.

**FT9:** Only use graphical symbols that are widely used and recognised.

Based on OT14, the system should show submitted content immediately on the SOL. As users are keen to see their comment to show up on the system, instant updates can reward mobile interaction and possibly reinforce their motivation to submit comments.

**FT10:** Show content immediately on the SOL after submission.

FT10 has profound implications for content moderation as it conflicts with pre-moderation approaches that necessarily involve a delay in comments showing up on the SOL.

Some findings in Table 27 further support requirements identified earlier, e.g. OT6 and OT17 support FT2 (Connection information should be available in all screens where user interaction is anticipated, including in help screens) while OT9 further supports FT3 (SOLs should provide a wide range of interaction methods and not rely on specific technologies, applications or social network membership).
8.4.4 Results from co-design activities

This section reports on participants' preferences for design alternatives and their alternative ideas for specific design aspects of SOLs. The findings are based on structured design sessions where participants were presented with paper prototypes of design alternatives and asked to choose their favourite or to describe or draw their own design ideas. In order to make the results more transparent, scaled-down versions of the paper prototypes used in the co-design sessions are presented together with charts indicating participants' preferences.

8.4.4.1 SOL Casing

In order to install SOLs in a gallery space, they need a casing that allows to mount them and connect them to a power source, supports enough space to fix an NFC tag and protect against inappropriate use or vandalism. Mounting displays has been identified as a major difficulty when installing interactive displays in gallery spaces (Gray et al., 2012) and other environments (Fitton and Cheverst, 2003). In addition, the appearance of the casing plays an important role as it should be aesthetically pleasing and integrate well with the environment (Ames and Dey, 2002; Mankoff and Dey, 2003, Pousman and Stasko, 2006).

![Design options for SOL casings (a,b,c) and participants' preferences (P1).](image)

Figure 45: Design options for SOL casings (a,b,c) and participants' preferences (P1).

The first question in the co-design session involved participants choosing a favourite among three designs for casings ranging from a rather unconventional shape to a more
conservative design. As shown in Figure 45.P1, the preferences are polarised between unconventional and conventional designs, with not a single participant choosing the more moderate design between the two. A majority of respondents (63%) preferred the more conventional design (Figure 45.c), some of which offered in open comments that it was more compact and "neat". The rest (37%) expressed a preference for the more unconventional design (Figure 45.a), offering as a reason that they found it resembled a speech bubble. Two participants who preferred the unconventional casing (Figure 45.a) indicated that they also liked the more conventional casing (Figure 45.c), making the conventional design the overall favourite.

FC1: SOLs should use simple, compact casings unless there is a clear reason for more unconventional designs

8.4.4.2 Information on the idle screen

The idle screen, which is displayed by default and therefore most likely to be seen by passers-by, is crucial in conveying the purpose, content and interactivity of SOLs. Fundamental design tensions for SOLs, such as to not distract from the exhibit while attracting enough attention to encourage engagement, need to be addressed in this screen. In particular, it has to present metadata about current comments, possibly provide information that helps visitors integrate it with other information in the environment (Brewer, 2004), convey that it is interactive (Ojala et al., 2012) and give users an idea of how to interact with it (Kules et al., 2004), while at the same time being glanceable (Matthews, Forlizzi, and Rohrbach, 2006) and presenting the information in a way that is easy to take in.

Participants were asked to choose a favourite design among several different options or alternatively draw their own design. In addition, they were asked which version of the user prompt in the screen they found most appropriate.

Figure 46.P2 suggests a spread of preferences among design variations, with designs (d) and (f) attracting the most votes. With regard to the user prompt in particular, Figure 46.P3 shows that most participants preferred the shorter version in design (d). Open comments suggest that many participants thought it self-evident that the "touch" refers to the screen.

Design (d) was also used in the user task carried out by participants at the beginning of the session, where open comments pointed out some problems with the design:

- Some participants assumed that the large number in the speech bubble is an object number rather than the number of comments. Suggestions on how to clarify what the number refers to include displaying the word "comments" underneath (inside the speech bubble) or changing the user prompt below the speech bubble to "Touch to read <number> comments".
Some participants pointed out that the prompt "Touch to read comments" does not inform users that they can also contribute comments, suggesting that this information should be integrated into the idle screen.

Some participants did not realise that the comments referred to the exhibit, suggesting that the SOL should additionally show an image of the exhibit to make this relation clearer, similar to design (f). One participant pointed out that the image might be useful when the SOL is installed further away but not necessary when installed right next to the exhibit.

Figure 46: Design options for the idle screens (d,e,f,g,h,j), participants' preferences (P2, P3) and participants' hand-drawn alternative ideas for screen designs (A1,A2,A3)

Three participants did not choose a preferred design from the presented options but instead contributed their own alternative designs (Figure 46.A1,A2,A3) addressing one or more of the problems discussed above.

FC2: SOLs should display short prompts that avoid stating the obvious
Chapter 8 Prototype design and evaluation

| FC3: SOLs should show descriptive labels for screen elements whose purpose is not entirely clear |
| FC4: SOLs should use clean, uncluttered screen designs |
| FC5: SOLs should display an image of the exhibit when installed further away to make the connection clear to users |

8.4.4.3 Representation of add button on browse screen

Once users touch the idle screen, they are presented with an interactive screen to browse current comments on the system. The bottom region of this browse screen shows information on how to submit comments, including a URL, a Twitter hashtag and a QR code. It also contains an "Add" button, which advertises the possibility to add own comments and, when pressed, provides a help screen explaining the various options to submit comments. Participants were presented with various visual designs for this button and asked to pick a favourite or draw an alternative.

![Design options for the Add button](image)

Figure 47: Design options for the Add button (l,m,n,o,p,q,r,s,t) and participants’ preferences (P4).

As Figure 47.P4 shows, more than half of all participants (56%) preferred a more explicit design for the add button (m) repeating the speech bubble from the idle screen and adding the words "add comment". Another group (31%) preferred a simple "add" (l) and the rest (13%) a minimalistic plus ("+") sign (t). The results further support the finding that SOLs should show descriptive labels for screen elements whose purpose is not entirely clear (see FC3 above).
8.4.4 Domain name preferences

One of the advertised interaction mechanisms involves users manually entering a URL on their mobile device in order to submit comments. An important design tension in this context is to make the URL recognisable and trustworthy while at the same time keeping its length to a minimum so that it can be displayed with a reasonable font size on the SOL and reduces typing on the mobile device.

With the recent introduction of new generic Top Level Domains (gTLDs) by the Internet Corporation for Assigned Names and Numbers (ICANN, 2015), one design variation considered using a gTLD in order to shorten the URL displayed on the SOL and give it a distinct identity. Participants were asked to choose between a design using a traditional and .com domain and another design using a novel .buzz domain resulting in a shorter overall URL.

A clear majority of participants prefer the traditional .com URL over the version using a new .buzz gTLD, even though the latter is shorter and therefore quicker to type (Figure 48.P5). This is consistent with Nielsen (1999), who suggests that users have been trained to recognise .com as the standard ending for web addresses and recommends to use a .com domain name for all sites that use English and address an international audience.

FC6: SOLs should use traditional top-level domains in their Web address unless there is a compelling reason to use generic domains.
8.4.4.5 Help screen

Offering an extra help screen that explains the interaction with SOLs in addition to displaying connection information in the browse screen implements the usability heuristic "Flexibility and efficiency of use" (Nielsen, 1995) which recommends to support both beginners and advanced users. It allows repeat users to directly connect their mobile to the SOL using the information provided in the Browse screen and offers more detailed information for first-time users who press the Add button instead.

![Figure 49 - continues next page]
Reflecting the information density of the help screen, several design aspects were under consideration. Participants were asked which URL representation, user prompts and general terminology they preferred.

As shown in Figure 49, most participants prefer an URL representation without the scheme (http://) qualifier, and there seems to be an equal split between those who think that an explicit World Wide Web subdomain (www.) is more recognisable and those who think the actual domain name and path (ubinote.com/16) are clear enough and easier to read.

Regarding the prompt asking users to visit a website with their mobile device, most participants prefer the simple "Visit <web address>"., followed by "Go to <web address>".
with other options receiving only single votes ("Navigate to <web address>") or no votes at all (Figure 49.P7).

Regarding the prompt asking users to use a certain hashtag on Twitter, most participants prefer the simple "Use <hashtag>", with only a small minority preferring "Tweet <hashtag>" or other variations such as omitting a verb altogether and only showing the hashtag (Figure 49.P8).

The preferred term for a QR code is "QR code" (Figure 49.P9), despite open comments suggesting that many people don't know what the "QR" stands for (Quick Response). This confirms earlier findings that, regardless of their troubled user experience, most people have heard about and recognise QR codes (Aguirre, Johnston and Kohn, 2011; Russell, 2011; Winter, 2015).

By contrast, people's experience with NFC tags is very limited, and this is reflected in the spread of preferences for the terminology for mobile interaction with an NFC tag. While most people prefer "Touch the NFC tag", other terms such as "Tap the NFC tag" or "Scan the NFC tag" are also popular (Figure 49.P10).

**FC7:** When displaying a human-readable Web address (URL) on SOLs there is no need to include the scheme component (e.g. http://)

**FC8:** SOLs should use plain, direct and commonly used terminology

### 8.4.4.6 Idle screen design

The last topic in the co-design sessions concerned a fundamental design decision in the evaluated prototype to only show connection information such as the URL, hashtag and QR code after a visitor touched the SOL screen. This design is informed by results from field trials indicating that visitors ignore SOLs when they see a QR code upfront, and that SOLs should support direct interaction to better integrate with the interaction environment in highly participative gallery environments (see 8.3). The evaluated design incorporates both of these aspects by supporting touch interaction and revealing the QR code only on the Browse screen shown in response to a touch.

One disadvantage of this design is that visitors need to first touch the SOL in order to connect their mobile phone, as otherwise the connection information is not visible. Participants were asked if they would prefer an alternative design, which permanently shows the connection information while still supporting direct interaction on the SOL to read comments.
Figure 50: Idle screen designs showing connection information (x1) or call to action (x2) and participants’ preferences (P11).

As Figure 50.P11 shows, there is a clear preference for the design revealing connection information only after direct interaction took place. The results confirm the earlier finding that SOLs should use clean, uncluttered screen designs (see FC4 above).

8.4.5 Results from standard questionnaires

In addition to the user task and co-design activity, participants were asked to optionally complete two standard questionnaires, including the System Usability Scale (SUS) described in Brooke (1996) to assess the usability of the current prototype, and Ogerstchnig and v.d. Heijden’s (2004) short form of the Hedonic value and Utility (HED-UT) scale developed by v.d. Heijden and Sørensen (2002) to measure its hedonic qualities and the utility.

The prototype achieved a SUS score of 78.1, which is significantly above the industry average of 68 (Sauro, 2011) but not in the top 10% of scores of 80.3 or higher, which is considered the point where users are more likely to recommend a product to a friend (ibid). While not helpful in identifying concrete usability problems, the current SUS score can serve as a baseline for future usability evaluations of the system.

Results on the HED-UT scale were 71.82 for hedonic value and 70.42 for utility. With a possible score between 0 and 100 the results are clearly positive, however, there are no large-scale studies available for the HED-UT scale that would provide a reference. Similar to the SUS, the HED-UT scale only provides an overall evaluation but no detailed information on how a system can be improved. The current values will therefore serve as bench marks for future iterations of SOLs.
8.4.6 Reflection on the research environment

The user-testing and co-design sessions were carried out in public environments and involved a mocked-up gallery exhibit (Figure 41a) and ad-hoc participant recruitment to take into account contextual factors influencing users’ behaviour and simulate the state of unpreparedness when museum visitors first encounter a SOL.

While this helped to increase the ecological validity of the study, it also decreased the level of control the researcher had over the environment and led to a number of problems affecting the data collection. These ranged from distractions at the start of some sessions causing the researcher to not properly focus the camera, to background noise on some video recordings making participants’ utterances difficult to understand during the data analysis, and to some participants not having enough time to complete the whole session.

Most of these issues can be addressed in future studies with minor script changes and better recording equipment, e.g. putting more emphasis on communicating session length and potential over-runs during participant recruitment could ensure that all participants have enough time to complete the whole session, while using a quality microphone and floor markings for camera and participant positioning could improve the quality of audio and video recordings.

8.4.7 Limitations

The study addressed criticism of user testing as lacking ecological validity by taking place in a public environment, and criticism of co-design as asking users to generate coherent and usable designs without the necessary technical knowledge and design skills by supporting sessions with paper prototypes of design variations for participants to comment on, indicate their preferences and optionally draw alternative ideas on paper.

While the sample size for both studies is relatively small, it is appropriate for formative evaluations and more than sufficient to discover at least 85% of usability problems in the evaluated prototype (Sauro and Lewis, 2012). Basic demographic information shows a good distribution with regard to age, gender, first language, interest in museums and digital literacy.

In addition to user testing and co-design sessions, participants also completed a set of standard questionnaires. In this context, the sample size is too small to draw reliable conclusions, however, the results can still be useful as an indicator of the magnitude of possible improvements and as a baseline for future evaluations.

With regard to transferability, the user testing and co-design sessions were based on a specific SOL prototype and related design alternatives. In addition to SOL-specific findings, both studies also produced more general findings that are relevant in a wider context, concerning the information design, terminology, learnability and interaction robustness of public interactive displays. However, as these findings emerged in a formative evaluation context and are based on a small sample, they need to be more rigorously evaluated before being generalised to other contexts.
8.4.8 Conclusions

This section has reported on user testing and co-design activities carried out in a mocked-up gallery environment in two locations, involving 16 participants recruited on the spot among students and staff from the College of Life, Health and Physical Sciences and the College of Arts and Humanities at the University on Brighton.

Results from user testing, which was video recorded and involved participants following the speak-out-loud protocol (Nielsen, 1994b) while interacting with a SOL prototype, suggest overall good learnability and usability of the evaluated prototype but also flagged up a number of aspects to improve in order to prepare SOLs for public use scenarios (FT1) and further improve usability and learnability (FT2 - FT8).

Results from the co-design sessions helped to inform specific design decisions for the next iteration of SOLs and in some cases indicate more general design preferences regarding the casing (FC1), information design (FC2, FC3, FC4, FC5), representation of Web address (FC6, FC7) and terminology (FC8) used on SOLs.

The achieved SUS score (Brooke, 1996) attests the evaluated design above-average usability while scores on the HED-UT scale (v.d. Heijden and Sørensen, 2002; Ogertschnig and v.d. Heijden, 2004) indicate positive ratings for hedonic value and utility. Both scores indicate room for further improvement and provide a baseline for future evaluations.

Carrying out the user-testing in a public setting increased its ecological validity but also led to problems affecting the data collection. Future studies should use appropriate protocols and quality recording equipment to mitigate these problems.
8.5 Field trial 2: Home\Sick

8.5.1 Introduction

A second empirical evaluation of SOLs in an authentic museum setting was carried out during the Home\Sick exhibition at SGD, which explored “how our homes might be reconfigured and reimagined as centres of connection in spite of emigration, of intimacy in spite of digital distraction, of food and energy production rather than consumption” (SGD, 2015). Carrying out the second field trial at SGD again ensured a basic level of consistency with the first study with regard to target audience, build environment and the open, participatory atmosphere in the gallery.

The evaluation involved SOL prototype 7 (see Appendix B7), which incorporates findings from the first field trial (see 8.3) and the formative user testing and co-design sessions (see 8.4). Unlike the first field trial, which evaluated a single SOL design that only supports mobile interaction, this second field trial involved a range of designs and interaction models, including mobile interaction and direct interaction on the SOL touch screen (see 8.5.3.1).

Research questions in this study centre around how much attention the new SOL designs attract, how much of that attention is converted into engagement and how visitors understand and interact with SOLs. Specific questions include:

- How much attention do SOLs attract and how does this compare to conventional object labels? Underlying assumptions include that the new screen designs attract more attention than earlier designs as they de-emphasise connection information and QR codes, but less attention than conventional object labels, which are a familiar feature in galleries and can be seen as a benchmark with regard to being noticed by visitors without unduly diverting attention from exhibits.

- How much engagement do SOLs generate and how do the different designs vary in engagement rates? Underlying assumptions include that support for direct interaction increases overall engagement and that designs with direct content browsing, questions posed by curators and exhibit-specific icons that integrate SOLs with the information environment fare better than their alternatives.

- How do visitors understand and interact with SOLs? Underlying assumptions include that visitors prefer direct touch interaction to mobile interaction, that content browsing in particular is very popular and that the SOL interface is easy enough to learn for most visitors to have no problems using it.

In addition, the evaluation explores visitors’ mental models of SOLs with regard to their assumed purpose and content and identifies motivations and barriers to engagement.

The following sections discuss the particular gallery deployment of SOLs in Home\Sick, describe the methodology of the evaluation and report on findings and their implications for future design iterations and deployments.
8.5.2 Gallery deployment

Four SOLs were installed in the *Home*Sick exhibition from 1-19 July 2015. The selection of exhibits was guided by the idea of social objects (Engeström, 2005; Simon, 2010), which provoke a reaction from visitors and stimulate debate, however, faced with realities on the ground, actual object selection was equally influenced by more pragmatic aspects such as availability of a mains power socket and artists’ agreement to have a SOL installed next to their exhibit.

Figure 51 to Figure 54 show the four SOL installations in the order in which visitors would typically encounter them when making their way through the exhibition.

In the ground floor gallery, SOL No.1 was integrated with *Parasite Farm*, which explores how agricultural practices can become part of urban living. The installation represents a complete nutrient cycle and consists of an indoor compost system and illuminated plant boxes integrated with conventional furniture. The SOL was placed on an empty shelf in a book case holding the plant boxes, occupying a central position and affording convenient access for direct interaction (Figure 51).

Also in the ground floor gallery, SOL No.2 was installed next to *LillyBot 2.0*, a personal microalgae farm that produces oxygen and *Chlorella* algae while binding carbon dioxide in the air. The exhibit reacts to visitors standing in front of it by boosting light exposure and carbon dioxide inflow to increase the alae’s metabolism, but otherwise offers no direct interaction opportunities. The SOL was placed on the right side of the plinth supporting the installation, in a peripheral position and requiring visitors to slightly bend down for direct interaction (Figure 52).

In the first floor gallery, SOL No.3 was integrated with *Ritual Machines*, which explores how technology can help to connect with family members away from home for extended periods. The installation consists of three exhibits, two of which are mock-ups of concepts and one, *Anticipation of Time*, a flip-dot display that can be controlled by visitors via two connected iPod touch\(^{28}\) devices. The SOL was placed next to *Anticipation of Time*, slightly set back from the display and the iPods, in a peripheral position but being within easy reach of visitors operating the iPod on the left side of the exhibit (Figure 53).

Also in the first floor gallery, SOL No.4 was installed next to *Dust Matter(s)*, which conceptualises domestic dust in the home as an indicator of the occupants’ outdoor activities. The exhibit consists of a range of ceramic vessels containing different dust samples and a video screen explaining how microscopic dust particles relate to different environments. The SOL was placed in a prominent position below a large video screen within easy reach for direct interaction (Figure 54).

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Figure 51: SOL1 (circled red) integrated with exhibit Parasite Farm in the ground-floor gallery.

Figure 52: SOL2 (circled red) integrated with exhibit LillyBot 2.0 in the ground-floor gallery.
Chapter 8 Prototype design and evaluation

Figure 53: SOL3 (circled red) integrated with exhibit Ritual Machines in the first-floor gallery.

Figure 54: SOL4 (circled red) next to exhibit Dust Matter(s) in the first-floor gallery.
8.5.2.1 Placement

As the evaluated prototype affords direct interaction, a robust casing was developed that presents the touchscreen at a suitable angle for ergonomic interaction at different heights. The casing was developed by SGD and fits in with the overall design of the exhibition. It has sharp angles (Figure 55) that limit placement options to avoid injury.

![Figure 55: SOL casing used in Home\Sick exhibition](image)

Besides common considerations for interactive public displays, such as having a sustained flow of people and sufficient space for interaction around them (Kules et al., 2004) and installing them at a suitable height for scanning markers with a mobile device (Hardy et al., 2010a), the actual placement of SOLs was also influenced by available mounting options, fit with the local ensemble and conformance with health and safety regulations. Three SOLs were placed on available horizontal surfaces (Figure 51, Figure 52, Figure 53) and one was mounted on a wall with ample space around it to minimise the risk of injury (Figure 54).

In order to better understand how placement might affect attention and engagement with SOLs, a tool was developed to assess the "attention potential" of placement options. The instrument uses a subset of factors identified by Bitgood (2009a, 2009b) to affect the level of attention that exhibits receive and provides a simple rating scale to quantify them for specific placements. Four of Bitgood’s (ibid) criteria, all of which relate to placement either in a local (exhibit) or global (gallery) context, were included:

- how many other stimuli are close by (Distraction)
- whether there is competition from other interaction opportunities (Competition)
- how often visitors have encountered a SOL in the gallery before (Satiation)
- at what stage during a visit they encounter the SOL (Fatigue)

Table 28 rates SOL installations along each of these criteria and combines individual scores to express their attention potential. It uses an arbitrary rating scale (1-4) reflecting the number of deployed SOLs and therefore simplifying ratings along the Satiation and Fatigue criteria. As the attention potential is calculated as a percent value, the rating scale only affects precision but not general validity. More critical, ratings are based on the subjective assessment of installations by the researcher and would benefit from a second rater. To mitigate this shortcoming, the table provides image references that allow readers to look at individual installations and critically evaluate the ratings in Table 28.
Chapter 8 Prototype design and evaluation

<table>
<thead>
<tr>
<th>SOL1</th>
<th>SOL2</th>
<th>SOL3</th>
<th>SOL4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Parasite Farm</td>
<td>LillyBot 2.0</td>
<td>Ritual Machines</td>
<td>Dust Matter(s)</td>
</tr>
</tbody>
</table>

### Distraction
- **SOL1**: SOL placed on otherwise empty shelf with little distraction apart from pot-plant above (see Figure 45).
- **SOL2**: SOL placed peripherally at foot of sensor-driven exhibit that dominates the scene (see Figure 46).
- **SOL3**: SOL placed peripherally next to interactive flip-dot display and two iPods to control the display (see Figure 47).
- **SOL4**: SOL placed prominently next to exhibit but below a large video screen that gets much attention (see Figure 48).

### Competition
- **SOL1**: There is an option to use a little spatula to dig in the plant box on the shelf below but this is often not noticed by visitors.
- **SOL2**: Another exhibit just five feet away invites visitors to control a blender by voice, which is very popular with visitors (see Figure 55c,d).
- **SOL3**: Visitors are invited to use two iPods in front of the exhibit to control an interactive flip-dot display, very popular (see Figure 55o,p).
- **SOL4**: There are no interaction possibilities at the exhibit or at other close-by exhibits.

### Satiation
- **1st SOL**: 1st SOL encountered in a typical gallery tour.
- **2nd SOL**: 2nd SOL encountered in a typical gallery tour.
- **3rd SOL**: 3rd SOL encountered in a typical gallery tour.
- **4th SOL**: 4th SOL encountered in a typical gallery tour.

### Fatigue
- **SOL1**: SOL installed in ground-floor gallery at 3rd exhibit in a typical gallery tour.
- **SOL2**: SOL installed in ground-floor gallery at 4th exhibit in a typical gallery tour.
- **SOL3**: SOL installed in first-floor gallery at 6th exhibit in a typical gallery tour.
- **SOL4**: SOL installed in first-floor gallery at 10th exhibit in a typical gallery tour.

### Attention potential
- **SOL1**: \( \frac{16 - 5}{16 - 4} = 92\% \)
- **SOL2**: \( \frac{16 - 10}{16 - 4} = 50\% \)
- **SOL3**: \( \frac{16 - 14}{16 - 4} = 17\% \)
- **SOL4**: \( \frac{16 - 12}{16 - 4} = 33\% \)

Table 28: Attention potential of individual SOL installations

Table 28 suggests that the attention potential of individual SOL installations varies considerably, ranging from a maximum of 92% for SOL1 to a minimum of 17% for SOL3. While this information could be used to discard a particular placement or to compensate for its attention potential by adjusting relevant design aspects, such as the luminosity of the display or the design of the casing, no mitigating measures were taken in this case to avoid compromising the experimental setup (see 8.5.3.1).

#### 8.5.2.2 Framing

Several measures were taken to provide visitors with information about the purpose and use of SOLs in the gallery space. These aimed to address a lack of framing as a barrier to engagement (see 8.3.4.2 and cf. Giannachi and Tolmie, 2012).
Briefing student mediators

Student mediators, a regular feature at SGD to engage visitors and explain exhibits, were briefed on the purpose and use of SOLs so that they were able to answer any questions by visitors. In order to not skew engagement numbers, mediators were asked not to promote or encourage the use of SOLs, but only offer explanations and help when asked by visitors.

Questions

Questions were developed for each exhibit (Figure 56) and displayed on the attached SOL (for designs that supported this feature, see 8.5.3.1). In addition to stimulating and focusing visitors’ interpretation of exhibits (Simon, 2010), questions provide a signal to visitors that helps to explain their purpose of encouraging interpretation and debate among visitors.

![Figure 56: Questions for Parasite Farm (a), LillyBot 2.0 (b), Ritual Machines (c) and Dust Matter(s) (d)](image)

Help screen

A help screen on the SOL explains the different ways in which users can connect their mobile device to browse, add, edit and rate comments (Figure 57). It is activated when a visitor touches otherwise non-interactive screen elements on the SOL.

![Figure 57: SOL Help screen for Dust Matters.](image)

Flyer

A flyer (Figure 58) was designed to explain the purpose and use of SOLs to visitors. The flyer was styled to fit with the Home\$ick gallery environment.
Figure 58: Flyer front (a) and back (b), explaining the purpose and use of SOLs to visitors. Note the flyer was ultimately NOT used in the study.

While originally meant to be available from the reception desk, the flyer was ultimately not used as it would have conflicted with common practice at SGD to not provide instructions for interactive objects in the gallery and instead rely on visitors’ curiosity and on student mediators to provide help and information.

8.5.2.3 Technical integration

Addressing shortcomings in an earlier prototype (see 8.3.2.2), the evaluated design (see Appendix B8) included functionality to report its battery level and connection status. In addition to making the information available via an admin dashboard (Figure 59a), the backend notifies administrators via email alerts (Figure 59b,c) when the battery level falls below pre-defined thresholds (20%, 15%, 10%) or when a SOL fails to contact the server for a pre-defined period of time indicating a loss of connectivity.

In the present deployment, SOLs 2-4 were connected to mains power while SOL1 ran on battery. Despite the admin dashboard, email notifications, supplied spare displays to be kept on charge and detailed instructions on how to swap out displays, SOL1 ran out of battery several times leaving a blank display in the gallery. While an underlying problem in this context might be a perceived lack of ownership, with technical staff understanding SOLs as a research prototype under the responsibility of the researcher rather than an in-house commenting system under their own responsibility, it also indicates that technical measures must be supported by appropriate organisational arrangements that clarify responsibilities and response procedures.
Chapter 8 Prototype design and evaluation

With regard to connectivity, SOLs were connected to a separate exhibition network available in the gallery space, which runs parallel to the free public WiFi available to visitors. Unlike in the first empirical study, where one SOL had intermittent connection problems (see 8.3.2.2), all SOLs in the present study had a reliable wireless network connection.

### 8.5.2.4 Information environment

While in the previous deployment (see 8.3.2.4) there was no integration of SOLs with the gallery’s information environment (Brewer, 2004), the present evaluation included design variations that integrated with the information environment by displaying an exhibit-specific icon on the idle screen, which was also printed on the related object label (Figure 60a-d). Alternative designs displayed a generic “touch” icon instead, which was meant to prompt visitors to interact with the touch screen (Figure 60e).

Other options to integrate SOLs with the exhibition’s information environment, for instance by displaying in-gallery SOL comments on the exhibition webpage via the available RSS feed and thereby enrich visitors' pre- and post-visit experience in Brown and Ratzkin’s (2011) Arc of Engagement, were not implemented at this stage.
8.5.2.5 Interaction environment

SGD offers free wireless internet access to visitors and has no restrictions on mobile phone use in the gallery space. As with all exhibitions at SGD, student mediators with knowledge of the exhibition topics were at hand in *Home\Sick* to answer questions about exhibits and involve visitors into discussions about related issues, and paper questionnaires and pens were laid out to collect feedback about the exhibition and SGD in general.

In addition, *Home\Sick* offered a large number of interactive installations where visitors could try out things, explore additional information and contribute their views (Table 29, Figure 61). These installations offered analogue and digital routes to participation suitable for a wide range of interaction preferences, capabilities and learning styles. The diversity of engagement opportunities is maybe best captured in a visitor statement made during an interview about SOLs (see below): "I think this whole exhibition is about trying things out".

As the evaluated SOL prototype supports both on-screen touch interaction and mobile interaction, there was some potential to leverage visitors’ previous interaction experience with other touchscreens in the gallery when first encountering a SOL.

<table>
<thead>
<tr>
<th>Title</th>
<th>Image</th>
<th>Interaction</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Washlab</td>
<td>Figure 61 (a, b)</td>
<td>Touchscreen</td>
<td>Touch display behind shower curtain where visitors complete survey of washing habits.</td>
</tr>
<tr>
<td>Blendie</td>
<td>Figure 61 (c, d)</td>
<td>Voice input, actuated blender</td>
<td>Voice-controlled blender actuated by visitors voicing sounds into an attached microphone.</td>
</tr>
<tr>
<td>Who's Home</td>
<td>Figure 61 (e, f)</td>
<td>Physical sliders, LED display</td>
<td>Physical sliders to control variables of Drake Equation (probability of intelligent life in universe), result shown on LED display.</td>
</tr>
<tr>
<td>Something to Write Home About</td>
<td>Figure 61 (g, h)</td>
<td>Pen and paper</td>
<td>Seats, postcards, pens, post box and cards displays for visitors to post thoughts that become part of the exhibition.</td>
</tr>
<tr>
<td>Host</td>
<td>Figure 61 (k, l)</td>
<td>Swab, agar plate, wall of samples</td>
<td>Moderated activity for visitors to take a swab of their bellybutton and streak it on an agar plate, where bacteria visibly multiply over time. The agar plate becomes part of the exhibition.</td>
</tr>
<tr>
<td>Bringing Health Home</td>
<td>Figure 61 (m, n)</td>
<td>Touchscreen, various sensors</td>
<td>Non-contact system monitoring breathing and movement of visitor resting on bed to provide sleep analysis on connected touch screen.</td>
</tr>
<tr>
<td>Ritual Machines</td>
<td>Figure 61 (o, p)</td>
<td>Touchscreens, flip-dot display</td>
<td>Large mechanical flip-dot display controlled by visitors via two attached iPods Touch devices.</td>
</tr>
<tr>
<td>Extracts of the Here &amp; Now</td>
<td>Figure 61 (q, r)</td>
<td>Labels, diary, audio player</td>
<td>Visitors invited to sit on chair or lie in sleeping bag, and listen to narration about Irish housing crisis or browse a redacted diary.</td>
</tr>
</tbody>
</table>

*Table 29: Interactive exhibits in Home\Sick*
Figure 61: Selection of interactive exhibits in Home\Sick, including Washlab (a,b), Blendie (c,d), Who’s Home (e,f), Something to Write Home About (g,h), Host (k,l), Bringing Health Home (m,n), Ritual Machines (o,p) and Extracts of the Here & Now (q,r).
8.5.3 Methodology

8.5.3.1 Experimental setup

Unlike the first evaluation at Fail Better, which involved a single SOL design that only supported mobile interaction, the present evaluation involved a range of designs. At their most basic, these can be grouped into designs with and without direct interaction content browsing. Designs with direct interaction content browsing (Figure 62a) enable visitors to browse comments on the SOL touch screen (in addition to their mobile device) but still require mobile interaction to post or rate comments. They aim to address the problem of unclear expectations about the content offered by SOLs, which has been identified as a barrier to engagement in the first evaluation (see 8.3.4.2). They also address the problem of QR code blindness, which caused visitors to ignore SOLs in a previous study (see 8.3.5.1), by showing QR codes only on the secondary browse screen. Designs without content browsing (Figure 62b) only support mobile interaction and show connection information on the idle screen, i.e. always visible without prior interaction. Both designs show a help screen when otherwise non-interactive regions of the screen are touched.

![Diagrams showing different interaction models for SOL designs with and without content browsing.](image)

Figure 62: Different interaction models for SOL designs with (a) and without (b) content browsing.

A second design variation concerns whether the idle screen displays a simple prompt or a question challenging visitors (Figure 63). Based on claims in the literature, questions can help to "activate a social object" (Simon, 2010, Chapter 4) and enable curators to direct and scaffold visitors' interpretation. They also can highlight specific aspects of an exhibit and thereby address a lack of interest, which was identified as a barrier to engagement in a previous study (see 8.3.4.2). Furthermore, it might help visitors to understand SOLs as a device for museums to ask questions and encourage interpretation, thereby helping to address a lack of framing as a barrier to engagement (ibid).
A third design variation concerns whether the idle screen displays a generic “touch screen” icon or an exhibit-specific icon also shown on the traditional object label (Figure 63). As the icon integrates with the information environment of the exhibit (Brewer, 2004), it might help visitors to understand SOLs as a social interpretation platform complementing the “official” interpretation on object labels and help to address a lack of framing identified in previous findings as a barrier to engagement (see 8.3.4.2).

The collected data can be segmented into designs with and without direct interaction content browsing, with and without question and with and without image (Figure 63).

Figure 63: Evaluated SOL designs A-G grouped into variations with and without direct interaction content browsing, with and without a question and with and without an image.
The study deliberately includes designs that vary in more than one parameter (e.g. designs with both image and question) and designs that implement features differently (e.g. designs with and without content browsing display the question in different ways). By exploring design variations in different combinations, the study embraces the multi-variant character of the naturalistic environment, where many contextual factors influencing visitors' attention and engagement with SOLs are beyond the researcher’s control, and looks for findings that can be generalised beyond specific configurations.

In order for each design to have the same exposure with respect to exhibit, time of day and day of week, the installed SOLs automatically switched between designs following a fixed schedule. Layout switches took place at the midpoint of the daily gallery opening times for each day, resulting in two designs being active each day. Switches were synchronised to ensure that all SOLs in the gallery used the same design at any given time to leverage recognition and prior learning when visitors encounter them at different exhibits.

### 8.5.3.2 Data collection and analysis

Table 30 lists the different data sets used in the evaluation and the aspects they help to investigate. Detailed information about each data set is provided in the following sections.

<table>
<thead>
<tr>
<th>Data set</th>
<th>Aspects the data helps to investigate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Observations</td>
<td>• awareness of SOLs&lt;br&gt;• engagement with SOLs</td>
</tr>
<tr>
<td>Visitor interviews</td>
<td>• mental models of SOLs&lt;br&gt;• user experience of SOLs&lt;br&gt;• barriers to engagement</td>
</tr>
<tr>
<td>Analytics data</td>
<td>• engagement with SOLs&lt;br&gt;• touch screen interaction with SOLs&lt;br&gt;• mobile interaction and preferred connection methods</td>
</tr>
<tr>
<td>SGD visitor numbers</td>
<td>• engagement rates for SOLs</td>
</tr>
</tbody>
</table>

*Table 30: Data sets and their purpose*

Visitor comments submitted to SOLs are a further interesting data set, however, the small number of contributions during the evaluation period (n=21, excluding seed comments) does not support a meaningful analysis of potential correlations between content quality and SOL design aspects.

### 8.5.3.2.1 Observations in the gallery

Observations in the gallery focused on visitors’ attention and engagement with SOLs. They were carried out without explicit consent in order not to disturb visitors’ natural behaviour. The researcher’s conduct during observation sessions was informed by the British Psychological Society's code of ethics, which restricts observations "[...] to those situations in which persons being studied would reasonably expect to be observed by strangers, with
reference to local cultural values and to the privacy of persons who, even while in a public space, may believe they are unobserved.” (British Psychological Society, 2011, p.13).

Observation notes were recorded in a coding template (see Appendix H) and then transferred into a spreadsheet. Quantitative data was summarised, segmented and analysed using standard statistical methods for user research discussed in Sauro and Lewis (2012). Qualitative observations were analysed using a two-step emergent coding scheme described in Miles and Huberman (1994) and then quantified where required.

Observations were carried out in two blocks from 1-4 July and 15-18 July 2015. The combined observation time was 28 hours and 56 minutes, during which a total of 812 encounters were observed. Encounters are conceptualised as situations where visitors have a clear chance to notice and engage with a SOL. As a minimum, this involves a visitor stopping at an exhibit. Visitors might then look at the exhibit, read the object label, look at and engage with the SOL in various ways.

The recorded observations are not evenly distributed among exhibits, SOL designs and SOL states. The data was therefore segmented and analysed for each exhibit and design variation, with attention and engagement rates expressed as percentages of observed encounters for each condition.

8.5.3.2.2 Visitor interviews

Structured interviews were carried out to understand visitors’ mental models and user experience of SOLs. Two sets of interview questions were used, one for visitors who had been observed to interact with SOLs and one for visitors who had not. Both versions of the interview were piloted with staff at the University of Brighton to refine wordings and identify common answers, which in turn informed the design of the coding sheet for note-taking during interviews (see evaluation instrument in Appendix H).

Visitors were approached by the researcher after their encounter with the exhibit and, possibly, their interaction with a SOL. Based on previous experiences (see 8.3), participants were not asked for written consent before the interview but simply informed about the research and given the opportunity to ask questions. This more informal procedure was cleared through the University of Brighton's standard ethics approval process.

Interviews lasted approx. 5 minutes and followed a fixed script to ensure consistency. Interviewees’ answers were recorded in a coding sheet with tick-boxes for common answers and space for open answers. A short section with demographic questions was filled in by participants at the end of the interview.

Notes were reviewed, clarified and amended immediately after each interview. They were then transferred into a spreadsheet for analysis. Quantitative data was aggregated and segmented as needed. Open answers were analysed using a two-step emergent coding scheme described in Miles and Huberman (1994), and then quantified as required.

A total of 66 visitor interviews were carried out, 39 with people who had not been observed to interact with SOLs and 27 with people who had been observed to interact with a SOL.
Despite efforts to select a balanced sample, the interviews involved more male than female participants (Figure 64a). The main reason for this is that many visitors attended as couples or groups, and, when approached for an interview, it was often a male member who would answer questions. A two-proportion z-test shows that there is no significant difference in gender composition between the two groups ($z = 0.117$, $p = 0.906$).

The age range of interviewees (Figure 64b) broadly reflects SGD’s target audience of young adults between 18-34 years but includes a slightly higher number than usual of older people as the evaluation period fell into the summer holiday season when many students are away and more tourists visit the gallery. A two sample t-test shows that there is no significant difference in age composition between the two groups ($t = 0.503$, $p = 0.617$).

Figure 65 shows that visitors who had been observed to interact with a SOL were slightly more likely to own a smartphone (89% vs. 85%, $z = 0.497$, $p = 0.619$), more experienced with QR codes (52% vs. 46%, $z = 0.455$, $p = 0.649$) and NFC tags (19% vs. 10%, $z = 0.962$, $p = 0.336$) but less likely to use Twitter on their mobile (22% vs. 31%, $z = 0.767$, $p = 0.443$), however, none of the differences is significant, indicating that both groups had comparable levels of experience with the mobile technologies involved in SOL interaction.
**8.5.3.2.3 Analytics data**

Analytics data was collected for touchscreen and mobile interaction with SOLs. Analytics data is transmitted to the backend in real-time, from where it can be interrogated via a data analytics and visualisation tool developed for this purpose (see 8.5.3.3).

Analytics data is structured into *sessions*. Direct interaction sessions start with a visitor touching the SOL idle screen, last as long as there is touch interaction on the browse or help screens and end with a timeout that returns to the idle screen. Mobile interaction sessions start with visitors calling up the Web application on their device and last as long as they browse, add, edit, rate or flag comments. Table 31 describes analytics data fields.

<table>
<thead>
<tr>
<th>Data field</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Date/Time</td>
<td>Segment data by date and time</td>
</tr>
<tr>
<td>Object ID</td>
<td>Segment data by exhibit</td>
</tr>
<tr>
<td>Layout ID</td>
<td>Segment data by SOL design</td>
</tr>
<tr>
<td>User ID</td>
<td>Identify unique/repeat users - 0 for SOL interaction -</td>
</tr>
<tr>
<td>PMI ID</td>
<td>Identify connection method (QR, NFC, URL) - 0 for SOL interaction -</td>
</tr>
<tr>
<td></td>
<td>Identify mobile interaction (browse, add, flag, etc.)</td>
</tr>
<tr>
<td>Log</td>
<td>Identify touch targets, precision, sequence, timing, assumed interactivity</td>
</tr>
<tr>
<td></td>
<td>Quantify interaction and model typical user journeys</td>
</tr>
<tr>
<td></td>
<td>---- Contains complete interaction data for one session in string format.</td>
</tr>
<tr>
<td></td>
<td>Uses following grammar to support efficient parsing (Extended Backus-Naur Form):</td>
</tr>
<tr>
<td></td>
<td>log = {[delim], entry, delim, time};</td>
</tr>
<tr>
<td></td>
<td>entry = touch</td>
</tr>
<tr>
<td></td>
<td>touch = coords, delim, target;</td>
</tr>
<tr>
<td></td>
<td>coords = &quot;[&quot;, {digits}, &quot;,&quot;, {digits}, &quot;]&quot;;</td>
</tr>
<tr>
<td></td>
<td>target = &quot;browse_next&quot;</td>
</tr>
<tr>
<td></td>
<td>event = &quot;browse_timeout&quot;</td>
</tr>
<tr>
<td></td>
<td>time = {digits};</td>
</tr>
<tr>
<td></td>
<td>digits = &quot;0&quot;</td>
</tr>
<tr>
<td></td>
<td>delim = &quot;.&quot;;</td>
</tr>
</tbody>
</table>

*Table 31: Analytics data fields and their purpose*

A total of 2,421 session logs were collected during the evaluation period (1-19 July). The data was prepared for analysis by excluding direct interaction logs involving admin tasks (e.g. display configuration, initial screen activation) and mobile interaction logs from demonstrations (e.g. to show visitors how NFC works). The latter were identified through user IDs relating to the mobile devices of the researcher and mediators. The resulting set of 1,921 session logs was used to analyse engagement and interaction with SOLs.
A key difference between mobile and direct interaction logs is that the former relate to specific users, while the latter are anonymous and can involve multiple visitors, e.g. when one visitor abandons the SOL and another engages before the screen times out.

**Figure 66:** Direct interaction session (black line) with four user journeys, starting with (a) visitor browsing comments, (b) disengaging, (c) second visitor browsing comments, calling up help screen, closing it, (d) disengaging, (e) third visitor browsing comments, calling up help screen, closing it, (f) disengaging, (g) fourth user browsing comments, (h) disengaging. No further interaction. Browse screen times out after 180 seconds, returns to the idle screen, session ends.

**Figure 67:** Direct interaction session (black line) with three user journeys, starting with (a) visitor browsing comments, (b) disengaging, (c) second visitor browsing comments, calling up help screen, closing it, continuing to browse comments, calling up help screen again, closing it, (d) disengaging, (e) third visitor calling up help screen without closing it, (f) disengaging. No further interaction. Help screen times out after 150 seconds, returns to browse screen, which times out after a further 30 seconds (180 sec total), returns to the idle screen, session ends.

**Figure 68:** Direct interaction session (black line) with two user journeys, starting with (a) visitor browsing comments, (b) disengaging, (c) second visitor browsing comments, calling up help screen, closing it, continuing to browse comments, calling up help screen again, closing it, browsing one more comment before (d) disengaging. No further interaction. Browse screen times out after 180 seconds, returns to idle screen, session ends.
In order to approximate the number of visitors engaging with SOLs, it is therefore necessary to determine the number of *user journeys* in direct interaction session logs. Figure 66 to Figure 68 show user journeys as periods of sustained interaction with short time intervals between touches and breaks between user journeys as long time intervals of inactivity.

Based on this observation, a *disengagement threshold* was identified as the minimum time of inactivity after which it can be assumed that following interactions belong to a different user. This involved two steps:

1. The timing data was classified into whole-second bins to produce a histogram (Figure 69), which gives a detailed overview of the distribution of time intervals. It shows the vast majority of interactions being apart only a few seconds and intervals becoming less frequent as they grow in length.

2. Jenks (1967) natural breaks classification was used to segment the time intervals into two clusters, representing touches during and between user journeys. The break point between these two clusters (55 sec / 37 sec for designs with / without content browsing) represents the disengagement threshold.

![Figure 69: Histogram of time intervals between interactions on SOL touch screen (logarithmic scale)](image)

The *disengagement threshold* was then used with the data analytics tool (see 8.5.3.3) to dynamically determine the number of individual user journeys for a given set of sessions. Total numbers based on 1,921 analytics data logs included 1,612 direct interaction sessions, 2,031 direct interaction user journeys and 109 mobile interaction sessions.

### 8.5.3.4 SGD visitor numbers

In order to establish a baseline of possible encounters with individual SOLs and design variations during the evaluation period, SGD’s in-house visitor numbers were consulted. The visitor numbers are based on automatic counters installed in the gallery and breakdown visits per day and time of day.

Estimates of *potential encounters* per SOL and design (see Figure 63 for designs A-G) are presented in Table 32. They take into account total visitor numbers for the evaluation period (4,208), daily visitor numbers, typical daily distribution of visitors, scheduled display times for specific SOL designs (see 8.5.3.1) and down-times for SOL1 (flat battery, see 8.5.2.2).
Table 32: Estimates of potential encounters with SOLs and designs

The estimates for potential encounters were used to calculate engagement rates for SOL installations and designs from analytics data, allowing for triangulation with engagement rates from observations, which are based on actual rather than potential encounters.

8.5.3.3 Data analytics and visualisation tool

A data analytics and visualisation tool (Figure 70) was developed to analyse the log data produced by SOLs both in real-time and post-hoc. The tool can be dynamically configured via query parameters and uses a simple state machine to analyse session data for a specific data set. It generates interactive visualisations and various statistics in order to:

- filter session data by exhibit, design, design variable, log ID, date and time
- classify and segment timing data to identify disengagement thresholds
- visualise sessions along a timeline for interactive exploration
- identify and count user journeys for a given subset of sessions
- examine detailed interaction data to identify patterns
- interactively play back touch interactions for a selected session

Generated visualisations include a timeline, which abstracts SOL interactions and states for each session in the selected data set, a replay facility where touch interactions for specific sessions are visualised and optionally a histogram showing the distribution of time intervals between interactions.

The timeline can be used to identify and examine interaction patterns and timings. In order to support this process, the granularity with which timing data is rendered can be controlled both interactively and through query parameters. Individual sessions can be selected interactively with mouse operations. Analytics data and interaction statistics for selected sessions are shown in tabular form together with underlying raw data points for further inspection.

The replay facility can be used to analyse how visitors interact with the SOL. It visualises touch interaction on the relevant SOL screen design for the selected session, reflecting the
exhibit, active design and SOL states during the interaction. Sessions can be played back interactively to identify touch patterns, how often and in which order functionality is used, which screen elements visitors assume to be interactive, etc.

Figure 70: Screenshot of analytics data visualisation tool. (a) Show help information and adjust timeline resolution; (b-g) Interactive timeline visualising sessions in selected data set; mouse-over to highlight sessions, click to select session for inspection; (b) Help state; (c) Touch on help screen; (d) Browse state; (e) Touch on browse screen; (f) Idle state at start and end of session; (g) Time in seconds; (h) SOL screenshots with overlaid touches; screens reflect active SOL design during selected session; (i) All session touches in chronological order; mouse-over to highlight touch on screenshot, use arrow keys to replay session; (k) Details and raw log for selected session; (l) Statistics for selected data set. Not shown in this screenshot are optional visualisations that are only generated when specific query parameters are set, such as the histogram of time intervals between interactions.
In addition to generating interactive data visualisations, the tool computes a range of statistics for the whole of the selected data set. These are made available in tabular form, together with underlying raw data points, for further inspection.

The analytics and visualisation tool is based on standard Web technologies (HTML, CSS, JavaScript, SVG). It has no external dependencies and runs in any standards compliant browser. It can be easily adapted for other display systems by modifying the parsing engine and state machine as required and by providing relevant screenshots of the analysed display screens on which to visualise touch interaction. The amount and type of statistical data produced by the tool can be adapted with simple code changes. The analytics and visualisation tool is available under an open-source license in the hope that it is useful to other researchers investigating public engagement with interactive pervasive displays.

An instance of the analytics and visualisation tool, using data from the Home\Sick exhibition only, is available at http://itrg.brighton.ac.uk/ubinote/aviz/index.php. A list of supported configuration parameters can be accessed via the help button at the top of the screen (Figure 70a).
8.5.4 Findings

8.5.4.1 Attention to SOLs

8.5.4.1.1 Attention per exhibit

Attention rates per exhibit (Figure 71) were calculated by dividing the number of people observed to look at the SOL by the total number of encounters observed for that exhibit.

![Figure 71: Observed attention to SOLs per exhibit](image)

There are marked differences in attention rates between exhibits despite SOLs using the same design at any given time, with attention to SOLs being highest at *Parasite Farm* (86.6%), decreasing considerably at *Lillybot 2.0* (60.8%), reaching its lowest at *Ritual Machines* (47.0%) and picking up again for *Dust Matter(s)* (61.7%). The data shows a strong and significant correlation \( r = 0.97, t = 5.80, p < 0.01 \) between attention rates and calculated attention potential (see 8.5.2.1) suggesting that placement-related factors are a good indicator of how much attention a particular SOL installation receives.

8.5.4.1.2 Attention to SOLs and traditional object labels

![Figure 72: Attention to SOL and object label per exhibit (a) and overall (b)](image)

While the data shows considerable differences in attention rates between individual SOLs and object labels (Figure 72), which again might be due to differences in placement, mean
attention rates across exhibits for SOLs (M = 64.0%, SD = 14.3%) and traditional object labels (M = 61.2%, SD = 12.0%) are on a similar level (Figure 72b). As the means are based on only four exhibits more research is needed to assess whether SOLs attracted similar levels of attention as object labels.

### 8.5.4.1.3 Attention per design variation

Attention rates per design variation (Figure 73, Table 33) were calculated by dividing the number of people observed to look at the SOL in idle mode (i.e. excluding encounters with SOLs showing browse or help screens, which are shared between designs) by the total number of encounters with idle screens observed for designs with that variation.

![Figure 73: Attention to SOL for designs with and without content browsing (a), with and without a question (b) and with and without an image (c).](image)

<table>
<thead>
<tr>
<th>Idle screen encounters</th>
<th>With browsing</th>
<th>Without browsing</th>
<th>With question</th>
<th>Without question</th>
<th>With image</th>
<th>Without image</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>216</td>
<td>300</td>
<td>318</td>
<td>249</td>
<td>332</td>
<td>187</td>
</tr>
<tr>
<td>Look at SOL</td>
<td>138</td>
<td>173</td>
<td>193</td>
<td>150</td>
<td>210</td>
<td>114</td>
</tr>
<tr>
<td>Attention rate</td>
<td>63.9%</td>
<td>57.7%</td>
<td>60.7%</td>
<td>60.2%</td>
<td>63.3%</td>
<td>61.0%</td>
</tr>
<tr>
<td>z-statistic</td>
<td>1.425</td>
<td>0.109</td>
<td>0.517</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>p-value</td>
<td>0.154</td>
<td>0.913</td>
<td>0.605</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Table 33: Differences in attention rates between evaluated design variables*

The data shows that designs with content browsing received more attention (63.9%) than without content browsing (57.7%), designs with question received more attention (60.7%) than without question (60.2%) and designs with image received more attention (63.3%) than without image (61.0%). A two-proportion z-test (Table 33) shows that none of the differences is significant, suggesting that differences in attention rates for different screen designs may be down to chance.
8.5.4.2 Engagement with SOLs

Based on analytics data and visitor data, the combined direct and mobile engagement rate per SOL was 13.9%. As this value is based on conservative estimates of user journeys and possible encounters with SOLs (see 8.5.3.2.3 and 8.5.3.2.4) the real engagement rate is probably closer to the observed engagement rate per SOL of 14.3%, which is based on actual encounters.

8.5.4.2.1 Engagement per exhibit

*Direct engagement*

Direct engagement rates per exhibit (Figure 74) were calculated from analytics data and visitor numbers by dividing the number of user journeys (see 8.5.3.2.3) for a SOL at a specific exhibit by the number of potential encounters with that SOL (see 8.5.3.2.4).

![Direct engagement with SOLs per exhibit](image)

*Based on 2031 user journeys and 15,446 possible encounters with SOLs

There are marked differences in engagement rates between exhibits, with engagement being highest at Parasite Farm (23.7%), decreasing considerably at Lillybot 2.0 (10.0%), reaching its lowest at Ritual Machines (5.4%) and picking up again for Dust Matter(s) (7.9%). The data shows a strong and significant correlation between attention and engagement rates \( r = 0.97, t = 5.52, p < 0.01 \), suggesting they are influenced by similar factors.

*Mobile engagement*

Mobile engagement rates per exhibit (Figure 75) were calculated from analytics data and visitor numbers by dividing the number of mobile interaction sessions with a SOL by the number of potential encounters with that SOL (see 8.5.3.2.4).

The mobile engagement rate is highest at Parasite Farm (1.28%), decreases at LillyBot 2.0 (0.97%), reaches its lowest point at Ritual Machines (0.38%) and stays at this level for Dust Matter(s). The data shows a strong and significant correlation between mobile and direct engagement rates \( r = 0.88, t = 2.60, p = 0.04 \). While this does not imply causality, a more cautious interpretation would be that they are influenced by similar factors.
One noteworthy difference is that direct engagement picks up again at Dust Matter(s) while mobile engagement remains flat. While this might be attributed to the relatively small sample, an alternative interpretation is that the additional physical and cognitive effort associated with connecting a mobile device to the SOL becomes more relevant in the later stages of a visit when a phenomenon called "museum fatigue" (Gilman, 1916; Davey, 2005; Bitgood, 2009a, 2009b) sets in.

Content contributions

Contribution rates per exhibit (Figure 76) were calculated by dividing the number of submitted comments per exhibit by the number of potential encounters for that exhibit (see 8.5.3.2.4).

The contribution rate is highest at Parasite Farm (0.25%), decreases at LillyBot 2.0 (0.17%), reaches its lowest point at Ritual Machines (0.05%) and increases again for Dust Matter(s) (0.12%). The data shows strong and significant correlations between contribution and mobile engagement rates ($r = 0.93$, $t = 3.49$, $p = 0.013$) and between contribution and direct engagement rates ($r = 0.92$, $t = 3.43$, $p = 0.014$), suggesting they are influenced by similar factors.
8.5.4.2.2 Engagement per design variation

Direct engagement

Direct engagement rates per design variation (Figure 77, Table 34) were calculated from analytics data and visitor numbers by dividing the number of direct interaction sessions (i.e. initial engagement with idle screen only rather than overall user journeys) for SOL designs by the number of potential encounters with the idle screen for SOL designs (see 8.5.3.2.4).

![Figure 77: Direct engagement rates for idle screen designs with and without browsing (a), with and without question (b) and with and without image (c)](image)

<table>
<thead>
<tr>
<th>Possible encounters</th>
<th>With browsing</th>
<th>Without browsing</th>
<th>With question</th>
<th>Without question</th>
<th>With image</th>
<th>Without image</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>With browsing</td>
<td>Without browsing</td>
<td>With question</td>
<td>Without question</td>
<td>With image</td>
<td>Without image</td>
</tr>
<tr>
<td>Direct engagement</td>
<td>5132</td>
<td>5302</td>
<td>5386</td>
<td>5261</td>
<td>5289</td>
<td>5143</td>
</tr>
<tr>
<td>Engagement rate</td>
<td>15.3%</td>
<td>12.2%</td>
<td>12.1%</td>
<td>14.6%</td>
<td>11.6%</td>
<td>14.5%</td>
</tr>
<tr>
<td>z-statistic</td>
<td>4.620</td>
<td>3.696</td>
<td>4.390</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>p-value</td>
<td>&lt; 0.01</td>
<td>&lt; 0.01</td>
<td>&lt; 0.01</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 34: Differences in direct engagement rates between design variations

The data (Table 34, Figure 77a) shows that idle screen designs for variations with content browsing attract significantly (p < 0.01) more direct engagement (15.3%) than designs without content browsing (12.2%). The result supports the assumption (see 8.5.3.1) that an overall simpler design that avoids showing complex connection information with a QR code on the idle screen increases engagement rates.

The data (Table 34, Figure 77b) further shows that designs posing a question to visitors have a significantly (p < 0.01) lower direct engagement rate (12.1%) than designs without a question (14.6%). The result seems to refute the assumption (see 8.5.3.1) that designs with a question generate more engagement, at least with respect to direct engagement on the SOL. Instead, a call to action, shown on alternative designs without a question, seems more effective in encouraging direct engagement.
Finally, the data (Table 34, Figure 77c) shows that designs with an exhibit-specific icon have a significantly ($p < 0.01$) lower direct engagement rate (11.6%) than designs without such an icon (14.5%). The result seems to refute the assumption (see 8.5.3.1) that designs with an exhibit-specific icon integrating the SOL with the information environment help visitors to associate it with the exhibit and lead to more engagement.

**Mobile engagement**

Mobile engagement rates per design variation (Figure 78, Table 35) were calculated from analytics data and visitor numbers by dividing the number of mobile interaction sessions for SOL designs with a specific design variation by the number of potential encounters with SOL designs with that design variation (see 8.5.3.2.4).

![Figure 78: Mobile engagement rates for designs with and without browsing (a), with and without question (b) and with and without image (c)](image)

<table>
<thead>
<tr>
<th>Possible encounters</th>
<th>With browsing</th>
<th>Without browsing</th>
<th>With question</th>
<th>Without question</th>
<th>With image</th>
<th>Without image</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mobile engagement</td>
<td>6890</td>
<td>5974</td>
<td>6816</td>
<td>6703</td>
<td>6732</td>
<td>6545</td>
</tr>
<tr>
<td>Engagement rate</td>
<td>43</td>
<td>53</td>
<td>48</td>
<td>42</td>
<td>40</td>
<td>51</td>
</tr>
<tr>
<td>z-statistic</td>
<td>0.62%</td>
<td>0.89%</td>
<td>0.70%</td>
<td>0.63%</td>
<td>0.59%</td>
<td>0.78%</td>
</tr>
<tr>
<td>p-value</td>
<td>1.729</td>
<td>0.555</td>
<td>1.292</td>
<td>0.083</td>
<td>0.578</td>
<td>0.196</td>
</tr>
</tbody>
</table>

**Table 35: Differences in mobile engagement rates between design variations**

The data (Figure 78, Table 35) shows that mobile engagement rates are almost inverse to direct engagement rates for designs with/without content browsing and with/without a question, although at a much lower level. Designs with content browsing have a lower mobile engagement rate (0.62%) than designs without content browsing (0.89%), designs with a question have a higher mobile engagement rate (0.70%) than designs without a question (0.63%) and designs with an exhibit-specific icon have a lower mobile engagement rate (0.59%) than designs without an exhibit-specific icon (0.78%). Due to the low mobile
engagement rates none of these differences is statistically significant and therefore cannot support any conclusions about the effect of these design features on mobile engagement.

**Content contributions**

Contribution rates per design variation (Figure 79, Table 36) were calculated by dividing the number of comments per design variation by the number of potential encounters with that design variation (see 8.5.3.2.4).

![Figure 79: Contribution rates for designs with and without browsing (a), with and without question (b) and with and without image (c)]

<table>
<thead>
<tr>
<th></th>
<th>With browsing</th>
<th>Without browsing</th>
<th>With question</th>
<th>Without question</th>
<th>With image</th>
<th>Without image</th>
</tr>
</thead>
<tbody>
<tr>
<td>Possible encounters</td>
<td>6890</td>
<td>5974</td>
<td>6816</td>
<td>6703</td>
<td>6732</td>
<td>6545</td>
</tr>
<tr>
<td>Contributions</td>
<td>9</td>
<td>9</td>
<td>12</td>
<td>5</td>
<td>8</td>
<td>11</td>
</tr>
<tr>
<td>Engagement rate</td>
<td>0.13%</td>
<td>0.15%</td>
<td>0.18%</td>
<td>0.07%</td>
<td>0.12%</td>
<td>0.17%</td>
</tr>
<tr>
<td>z-statistic</td>
<td>0.303</td>
<td>1.664</td>
<td>0.750</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>p-value</td>
<td>0.762</td>
<td>0.096</td>
<td>0.453</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Table 36: Differences in contribution rates between design variations*

Designs with content browsing have a lower contribution rate (0.13%) than designs without content browsing (0.15%), designs with a question have a higher contribution rate (0.18%) than designs without content a question (0.07%) and designs with an exhibit-specific icon have a lower contribution rate (0.12%) than designs without an icon (0.17%). Due to the overall low contribution rates none of these differences is statistically significant and therefore cannot support any conclusions about the effect of these design features on contribution rates.
8.5.4.3 Interaction with SOLs

8.5.4.3.1 Direct touch interaction

Visualisations accumulating touches on SOL idle screen designs help to identify users' assumptions about interactivity. In idle screens, visitors target primarily the "touch" icon (Figure 80 a,b,d) and the speech bubble showing the current comment count (Figure 80 all).

![Figure 80: Accumulated touches filtered with 1000ms double-tap threshold, based on four hours exposure time each for designs with (a,b,c) and without (d,e,f) content browsing]

A considerable number of touches were recorded on other screen areas. While this can be interpreted as people understanding screen elements as *faux affordances* (Saffer, 2013) and correctly assuming that in fact the whole screen is interactive with a single action.
regardless of the touch target, a more likely interpretation is that these touches do not necessarily reflect information seeking behaviour but can be understood as probing touches used to test interactivity and explore the user interface.

Figure 81 shows accumulated touch interaction on the browse screen, which is shared between designs with content browsing, and the help screen, which is shared between all designs.

![Figure 81: Accumulated touches filtered with 1000ms double-tap threshold for browse screen, based on 12 hours exposure time (b) and help screen based on 24 hours exposure time (d). Screen without touch visualisations provided for reference (a, c).](image)

For the browse screen, the visualisation indicates that the navigation buttons are popular touch targets. Analytics data shows that they were used a total of 5,339 times. Visitors typically browsed to the right, reflecting the left-to-right writing system in western cultures. Accordingly, the next button was pressed a total of 4,268 times, averaging 3.09 per user journey, while the previous button was pressed only 1,071 times, averaging 0.77 per user journey. Together, the numbers suggest that visitors read on average 4.86 comments per user journey (including the initially displayed comment when activating the browse screen). Other popular touch targets on the browse screen include the speech bubble with the text “add comment” and, surprisingly, the thumbs up/down icons with counters.
For the help screen, the most used touch target is the “OK, got it” button, which will be familiar to most users from conventional WIMP\textsuperscript{39} interfaces. The fact that the QR code, URL and Twitter hashtag attract only slightly more touches than other parts of the screen suggests that only some users assume them to be touch targets.

Table 37 summarises screen elements commonly assumed by visitors to be touch targets on idle, browse and help screens.

<table>
<thead>
<tr>
<th>Category</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>Graphical elements that suggest interactivity</td>
<td>• Touch screen icon (Figure 80a,b,d)</td>
</tr>
<tr>
<td></td>
<td>• Speech bubble with &quot;add comment&quot; prompt (Figure 81a,b,c)</td>
</tr>
<tr>
<td>Elements that display dynamic content</td>
<td>• Speech bubble with current comment count (Figure 80, all)</td>
</tr>
<tr>
<td></td>
<td>• Thumbs-up and -down icons with numbers indicating past votes (Figure 81a,b,c)</td>
</tr>
<tr>
<td>Elements that resemble a button</td>
<td>• Navigation buttons (Figure 81a,b,c)</td>
</tr>
<tr>
<td></td>
<td>• &quot;OK, got it&quot; button (Figure 81d,e,f)</td>
</tr>
</tbody>
</table>

\textit{Table 37: Interface elements assumed to be interactive touch targets}

Putting these results into perspective, observations in the gallery suggest that screen touches do not always reflect intent to engage meaningfully. Several visitors were observed to interact with a SOL seemingly for its own sake rather than to access any information, e.g. flicking through comments without reading them or touching the screen and immediately moving on without looking at the result. While the value of such interaction is debatable, it is an indicator of the strong appeal of interactivity in itself and must be considered when evaluating quantitative measures of engagement.

In addition to data about users’ interaction, the analytics data also holds information about non-interaction that can inform the design of SOLs. In particular, the data shows that the browse screen (in designs with content browsing) timed out 966 times in 1,527 user journeys (63%) and the help screen (across all designs) timed out 312 times in 1,491 help screen activations (21%), the latter despite the availability of a button to close the help information, confirming the need for timeouts in direct interaction mode.

\textbf{8.5.4.3.2 Physical mobile interaction}

The analytics data includes logs for 109 mobile interaction sessions involving a total of 68 individual visitors. 67 sessions were initiated via an NFC scan, 27 via a QR code scan, 13 via manual URL input and 2 via Twitter using the exhibit-specific hashtag shown on the SOL (Figure 82a). The number of individuals using these connection methods shows a similar

\textsuperscript{39} WIMP stands for “windows, icons, menus, pointer” desktop computing user interfaces.
distribution, with 40 people using NFC, 20 QR codes, 6 manual URL input and 2 Twitter (Figure 82b). Not a single visitor used more than one connection method, suggesting that people tend to stick with one method instead of experimenting with different technologies.

![Image](image1.png)

*Figure 82: Visitors’ mobile interaction with SOLs, quantifying use of different connection methods (a) and how many people they were used by (b)*

Analytics data shows that NFC tags were scanned more than twice as often as QR codes, despite most visitors having previous experience with QR codes but not with NFC tags (see 8.5.3.2.2). A likely explanation for this anomaly is that the NFC tag was integrated into the SOL casing and therefore more prominent, while the QR code, URL and Twitter hashtag were shown on the SOL e-ink screen and, at least in designs with content browsing, only visible after touching the idle screen.

![Image](image2.png)

*Figure 83: Use of different mobile connection methods for designs with and without content browsing*

The difference is less pronounced for designs without content browsing (Figure 83), where the QR code, URL and Twitter hashtag are always visible, however, even in this condition NFC was the most-used connection method. The results show the importance of making connection options obvious to potential users and indicate that their conspicuousness has more impact on uptake than people’s self-reported familiarity with different methods.
It also confirms observations in the gallery suggesting that the NFC symbol developed for SOLs was well understood by visitors. While SOLs were initially equipped with the original NFC symbol as provided by the manufacturer (Figure 84a), observations on the first day of deployment showed that many visitors touched the NFC tag like a button, similar to the visitor behaviour observed in the first evaluation study (see 8.3). In one observation session as many as 3 out of 20 encounters involved a visitor touching the NFC tag like a button.

![Figure 84: NFC symbols (actual size): manufacturer's design (a) and custom design for SOLs (b)](image)

In order to address this problem, the original NFC symbol was replaced after the first day with a custom design depicting a mobile device and without the word "touch" (Figure 84b). The effect of this change was immediately noticeable, with no further observations of visitors touching the NFC tag like a button from that day onwards.

Interaction logs show that only 4.6% of mobile interactions happened within 30 seconds of the last direct interaction on the related SOL, another 4.6% within 60 seconds and another 10.1% within 3 minutes, while the vast majority of 80.7% of mobile interactions were initiated more than 3 minutes after the last direct interaction on the SOL (Figure 85). The numbers suggest that direct and mobile interaction are largely independent of each other. This interpretation is further supported by observations in the gallery, where seven out of eight observed mobile interactions with a SOL were initiated directly without any prior interaction on the touch screen. Only a single observed mobile interaction was initiated after the visitor had browsed comments on the SOL touchscreen.

![Figure 85: Time between last recorded touch screen interaction and mobile interaction](image)
Together, analytics and observation data refute two key assumptions in the evaluated SOL design: Firstly, that reading other visitors’ comments through direct interaction on the SOL stimulates mobile engagement and content contributions, and secondly, that a help screen explaining how to connect a mobile device to the SOL increases mobile engagement by helping people to overcome technical barriers. Instead, the data suggest that mobile interaction is largely de-coupled from touchscreen interaction and perceived by visitors as an alternative to, rather than a continuation of, direct interaction. Furthermore, the data suggests that visitors who choose mobile interaction over touchscreen interaction know how to connect their device from the outset and do not require technical help.

8.5.4.3.3 Mobile interaction

Visitors’ interactions on the mobile device after connecting it to the SOL are shown in Figure 86. Unsurprisingly, the most common interaction on the mobile device is browsing comments as this is the default view visitors are presented with after scanning a SOL. The number of browsing sessions is higher than the total of 109 mobile interaction sessions as it includes rescans of the same SOL and browser refreshes. 27 visitors (25%) pressed the “Add Comment” button leading to a commenting screen and 20 visitors (18%) actually submitted a comment. Only 8 visitors (7%) used the thumbs up/down voting mechanism to rate other visitors’ comments, all of which gave a thumbs up. Only one visitor pressed the button to flag a comment, however, this was not actually submitted. Two visitors engaged via Twitter by sending a tweet with the relevant exhibit-specific hashtag monitored and harvested by the SOL backend.

Figure 86: Functionality used by visitors after connecting mobile device to SOL

8.5.4.4 Mental models and user experience of SOLs

8.5.4.4.1 Assumptions about purpose

Interviews suggest that a majority of visitors were unclear about the purpose of SOLs. Responses from people who did not interact with SOLs show that while 49% correctly assumed that SOLs are for commenting, 28% thought they provide information, 28% answered that they do not know and 15% offered other assumptions ranging from generic
(e.g. "online stuff", "social media") to specific (e.g. "adjust the volume [of video screen above SOL4]", "Maybe it’s for a prize draw?"). Some visitors offered multiple assumptions, taking the total in Figure 87 over 100%.

Responses from people who did interact with SOLs show that initial assumptions about their purpose were evenly split between being a platform for visitor comments (30%) and providing information (30%). A large number answered that at first they did not know what SOLs might be for (44%), suggesting that an important driver for initial engagement was curiosity rather than an intention to use commenting functionality or access information.

### 8.5.4.4.2 Assumptions about interactivity

Interview questions exploring assumptions about interactivity were only posed to visitors who had not been observed to interact with SOLs, as visitors who did interact evidently realised they are interactive.

When asked about interactivity, 67% of respondents thought SOLs were interactive, while 23% assumed they were not interactive and 10% were not sure (Figure 88a). Open comments suggest that the main reason for people assuming SOLs to not be interactive was the lack of luminance of the e-ink display. Answers to this effect included "the screen seems off", "the light is not on, looks unplugged" and "it looks dead".

---

**Figure 87: Interviewees’ assumptions about the purpose of SOLs**

**Figure 88: Interviewees’ assumptions about interactivity (a) and mode of interaction (b).**
As asked how they might use the SOL, most respondents were able to correctly identify at least one supported interaction mode. 28% said they would scan the QR code, 31% would scan the NFC tag and 33% would touch the screen. 10% answered more vaguely that they would use their mobile phone and 5% suggested to use the Twitter hashtag. 21% initially said they did not know but then offered valid interaction methods as second guesses.

8.5.4.4.3 Assumptions about content

When asked what kind of content they would receive when interacting with a SOL (Figure 89), 41% of respondents who did not interact with SOLs answered they would expect "information", 21% would expect a "website" and 23% "comments". 15% of respondents offered a range of other assumptions, including "audio", "a question" and "ask me to install an app". Many respondents offered more than one answer or started their answer with a "not sure" (18%). By contrast, visitors who were observed to interact with a SOL had much clearer expectations with 59% answering that they had expected information while 41% had expected comments. Only 7% of respondents answered they had been not sure. None had expected a website or "other" content, which is in stark contrast to visitors who did not interact with a SOL.

![Figure 89: Assumed content of SOLs](image)

The answers suggest that in addition to explicitly mentioned factors influencing engagement (see below), unclear or wrong expectations about the content are barriers to engagement. For instance, as many websites display poorly on mobile devices and cause visitors to leave early and not return (Budui, 2015), expectations of a "website" might be associated with a poor user experience. Likewise, as most users do not like being asked to download a mobile app (Morell, 2015), expectations of being asked to do so might deter visitors from engaging.

8.5.4.4.4 Factors influencing engagement and content contribution

When asked "What would make you try it [the SOL] out?" (Figure 90), interviewees who had not been observed to interact with SOLs offered a wide range of reasons why they had not engaged and what would make them interact with SOLs. The answers suggest that technological aspects (23%) and a general predisposition to not use a commenting system (23%) and are the two biggest barriers to engagement, closely followed by a lack of interest.
in the exhibit or the discourse (18%). Other reasons relate to a lack of supporting information or signage (10%), the SOL design and positioning (10%) and not having seen anyone else using it (8%). Some respondents offered no answer to this question (8%).

Interviewees who had been observed to interact with SOLs without contributing a comment were asked the related question "What would make you add a comment?" (Figure 90). Responses suggest that interest in the exhibit or discourse (42%) is the most important factor for content contribution, followed by technological aspects (19%) and a general predisposition to not write comments (19%). Some respondents mentioned a lack of supporting information or signage (8%) and some mentioned aspects relating to the design or positioning of SOLs (8%). Again, 8% did not provide an answer to the question.

Example answers for each of the defined categories are provided in Table 38. Some responses clearly refer to specific design variations or installations, e.g. the comment "If I could see what other people write" (P39a) was made in reference to a layout without comment browsing, "If there was a question it wants me to comment on" (P14b) was made in reference to a SOL design without question and "It should be on eye height, I don't like to reach down" (P9b) was made in reference to SOL2 installed at LillyBot 2.0, where people needed to bend down to touch the screen or connect their mobile device.

Technological barriers generally refer to mobile interaction and can be categorised into:

- mobile literacy
  e.g. "I don't know how NFC works" (P19a); "This is not my world" (P31a),

- technical capability
  e.g. "My phone has no NFC" (P18a); "I don't have a QR code reader installed" (P3a)

- connectivity
  e.g. "I have no WiFi here." (P23b); "If my phone would work over here" (P28a).

Many of these problems cannot be addressed effectively at the application level and require higher-level changes beyond the designer's control, such as the emergence of a
simple, ubiquitous and universally accepted technology for physical-mobile interaction (beyond NFC, QR codes and manual URL input) and seamless low-cost wireless connectivity.

<table>
<thead>
<tr>
<th>Category</th>
<th>Engagement</th>
<th>Contribution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Predisposition</td>
<td>People who did NOT interact with SOL: “What would make you try it out?”</td>
<td>People who DID interact with SOL: “What would make you add a comment?”</td>
</tr>
<tr>
<td></td>
<td>&quot;I don't usually make comments&quot; (P4a)</td>
<td>&quot;I wouldn't.&quot; (P11b)</td>
</tr>
<tr>
<td></td>
<td>&quot;Generally I'm not that much into interactive stuff.&quot; (P36a)</td>
<td>&quot;I usually don't make comments.&quot; (P8b)</td>
</tr>
<tr>
<td>Interest in object or discourse</td>
<td>18% &quot;If it's something really interesting.&quot; (P39a)</td>
<td>42% &quot;If I'm particularly interested [in the exhibit].&quot; (P12b)</td>
</tr>
<tr>
<td></td>
<td>&quot;Maybe if I feel I have something to say&quot; (P14a)</td>
<td>&quot;If I have something interesting to say.&quot; (P24b)</td>
</tr>
<tr>
<td>Technology</td>
<td>23% &quot;I don't have a QR code reader installed&quot; (P3a)</td>
<td>19% &quot;I'm not using Twitter or such things [QR]. What is NFC?&quot; (P13b)</td>
</tr>
<tr>
<td></td>
<td>&quot;If my phone had NFC I would try it out&quot; (P30a)</td>
<td>&quot;I have no WiFi here.&quot; (P23b)</td>
</tr>
<tr>
<td>Supporting information or signage</td>
<td>10% &quot;I didn't see any instructions; usually there are instructions...&quot; (P11a)</td>
<td>8% &quot;If there were instructions, explanations.&quot; (P5b)</td>
</tr>
<tr>
<td></td>
<td>&quot;Maybe a big sign&quot; (P8a)</td>
<td>&quot;If there was a question, what it wants me to comment on.&quot; (P14b)</td>
</tr>
<tr>
<td>Design and positioning</td>
<td>10% &quot;Maybe a flashing button. It needs to invite me more.&quot; (P16a)</td>
<td>8% &quot;The screen should be more colourful.&quot; (P8b)</td>
</tr>
<tr>
<td></td>
<td>&quot;Maybe more colour and a brighter screen&quot; (P10a)</td>
<td>&quot;It should be on eye height, I don't like to reach down.&quot; (P9b)</td>
</tr>
<tr>
<td>See others using it</td>
<td>8% &quot;If I see somebody else use it&quot; (P26a)</td>
<td>0% -/-(P26a)</td>
</tr>
<tr>
<td></td>
<td>&quot;If I could see what other people write&quot; (P39a)</td>
<td>-/-</td>
</tr>
<tr>
<td>Other</td>
<td>23% &quot;My kids would make me try it out&quot; (P8a)</td>
<td>0% -/-</td>
</tr>
<tr>
<td></td>
<td>&quot;If I had more energy&quot; (P31a)</td>
<td>-/-</td>
</tr>
</tbody>
</table>

Table 38: Categories and example answers for motivations and barriers to engagement

In order to identify any barriers to engagement not specifically related to SOLs but more generally to the use of mobile devices, visitors who had not engaged with SOLs were asked three questions exploring their attitudes towards smartphone use in galleries (Figure 91). The answers show that 67% of respondents think it is "OK for people to use their mobile in a gallery space, for example to take a picture or to look up information" and the remaining 33% think it is acceptable if it does not disturb others (Figure 91a).

From a first-person perspective, 16% of respondents say that it would spoil their experience to use a mobile phone in the gallery, while 70% say it would not spoil the experience and
14% say it depends on the type of gallery (Figure 91b), e.g. it might spoil the experience in an art gallery but not in a hands-on science gallery.

With regard to SGD in particular, 95% of respondents think that mobile phone use is welcome in the gallery while 5% were not sure (Figure 91c).

Together, the answers suggest that overall visitors have a critical but open attitude to the use of mobile devices in galleries, showing awareness of potential negative aspects but generally approving mobile phone use for purposes related to the gallery visit. Most visitors correctly read that mobile phone use is welcome at SGD and while personal preferences might be a barrier to mobile engagement for some, this is not the case for the majority.

### 8.5.4.4.5 User experience and intent to use again

Visitors who had been observed to engage with a SOL were asked several questions probing their user experience. In response to the question "Was it clear how it [the SOL] works?", 81% of interviewees answered Yes while 15% were not sure 4% answered No (Figure 92a). Given that most respondents can be assumed to be first-time users, the responses indicate overall a good level of learnability for the current design.

When asked "Was it worth using it?", 59% answered Yes, 22% were not sure and 19% answered No. Considering that answers to this question might be positively biased by interviewees trying to give "the right answer" (Turnock and Gibson, 2001; Robson, 2002), the satisfaction rate of 59% seems low. Answers to an earlier question might hold the key in this context: As 59% of interviewees who engaged with SOLs expected to be presented with information, when in fact they were presented with visitor comments and/or a help screen, more clarity about the content to expect might help to increase satisfaction levels.

Complementing the above questions, interviewees were finally asked "Would you use it again when you see it somewhere else?" (Figure 92c). Most respondents answered Yes (67%) or Probably Yes (11%) to this question, with 15% being undecided and 7% answering Probably Not. While again these answers might be biased by interviewees trying to give "the right answer" (Turnock and Gibson, 2001; Robson, 2002), the responses suggest that most interviewees found the experience engaging enough to use a SOL again in the future.
8.5.5 Discussion

8.5.5.1 Design implications for SOLs

Casing and display

The current SOL design, based on a monochrome greyscale e-ink screen and a casing that integrates with the wider exhibition design, achieves a good balance between attracting attention and not distracting from the exhibit. Visitor interviews suggest that both attention and engagement could be increased by making SOLs more conspicuous and more obviously interactive, for instance by making the casing stand out from the exhibition environment rather than blend in or by using an active colour display instead of a passive monochrome display. Future design iterations should support a wider range of displays and casings that can be used to increase attention and engagement where appropriate. More luminous displays in particular would widen the range of deployment options as the current e-ink screens are not suitable for darker environments.

On-screen content browsing

Content browsing on the SOL touch screen proved very popular with visitors, accounting for most of visitors’ direct interaction and far surpassing mobile interaction. While the data does not support the original assumption that reading comments on the SOL might inspire visitors to connect their mobile device and contribute their own, it clearly shows that...
support for direct interaction considerably boosts overall engagement and reaches visitors who otherwise might not have engaged with the SOL. Future design iterations should therefore continue to support content browsing via direct interaction, primarily on the grounds that it widens participation, and explore ways to exploit its popularity to raise contribution levels, e.g. by injecting questions (see below) into the stream of visitor comments after a certain amount of browsing. Findings about the average number of comments read in a user journey (see 8.5.4.3.1) provide useful information in this context.

**Asking questions**

Designs asking a question had significantly lower direct engagement rates than alternative designs, whereas differences in mobile interaction and content contributions were not statistically significant. The results do not support for the original assumption that a question increases engagement by generating interest and framing visitors' participation. Future design iterations should explore alternative ways to present questions (see above) and investigate what types of questions are most effective in increasing content contributions on SOLs. Literature discussing questions as a means to increase participation in museums (e.g. Hohenstein and Tran, 2007; Simon, 2009) can provide valuable guidance in this respect.

**Using exhibit-specific icons**

Designs with an exhibit-specific icon had consistently lower engagement rates than alternative designs. The results refute the assumption that an exhibit-specific icon that integrates the SOL with the information environment (Brewer, 2004) increases engagement and puts into question the underlying assumption that it helps visitors to associate the SOL with the exhibit and consequently to understand it as a public alternative to the "official" narrative on traditional object labels. Future design iterations should abandon the idea of exhibit-specific icons on the SOL and instead focus on calls to action, which have proved more successful in encouraging interaction.

**Touch screen interaction**

The analysis of direct screen interaction has revealed the types of interface elements visitors most commonly assume to be interactive (see 8.5.4.3.1). While the current design provides appropriate interaction feedback for most of these elements, future design iterations should explore the value of providing more differentiated responses, e.g. contextualised help depending on what screen element was touched. The large number of exploratory touches, touches without intent to engage and double-taps hints at potential for improvement. Automatically detecting and interpreting such behaviour holds potential to personalise the user experience and react to curiosity, boredom and frustration.

**Physical mobile interaction**

Visitors used all supported technologies to connect mobile devices to SOLs, suggesting that the current range of methods should be kept or even extended in future design variations.
NFC was used for more than half of all mobile connections, despite the vast majority of interviewed visitors reporting not having used the technology before. As NFC was the only method not advertised on the SOL screen but permanently visible on the casing, future design iterations should explore whether displaying connection information permanently and separate from the actual content on the SOL display can increase mobile interaction across methods.

Help information
The data showed an almost complete disconnect between direct and mobile interaction (see 8.5.4.2), putting into question the usefulness of detailed information in the current help screen explaining how to connect a mobile device. Future design iterations might instead provide more high-level information in the help screen that helps to frame and contextualise SOLs in the museum. Drawing on findings from the visitor survey (Chapter 5) and from visitor interviews in the present study (see 8.5.4.4.4), this could include who reads the comments, how they are moderated, how long they are stored and how they might be reused by the organisation.

Personalisation
Lastly, several aspects related to generating engagement and supporting interaction could be improved considerably if SOLs would be able to recognise users and, by extension, distinguish between first-time and repeat users. For instance, help information could be made more prominent for first-time users and less prominent for repeat users to reduce interface complexity; given that visitors tend to stick to the same technology when connecting their mobile device (see 8.5.4.3.2), connection information could be simplified based on previous interaction in order to to improve efficiency; personalised questions or prompts could be shown for visitors whose previous interaction indicates that they are bored or frustrated. Future design iterations should explore non-intrusive ways for SOLs to identify users while protecting their privacy and anonymity.

8.5.5.2 Implications for the placement of SOLs
The results show significant differences in attention and engagement rates between individual SOL installations that far outweigh the small and mostly insignificant differences between design variations (see 8.5.4.1 and 8.5.4.2). Comparing the attention and engagement rates for specific SOL installations with their attention potential (see 8.5.2.1) reveals strong and significant correlations (Figure 93, Table 39).
Figure 93: Correlation between attention potential and measured attention and engagement. The diagram shows values proportionally rebased to the attention potential of SOL1 (Parasite Farm).

<table>
<thead>
<tr>
<th></th>
<th>Attention potential</th>
<th>Attention (observed)</th>
<th>Direct Eng. (observed)</th>
<th>Direct Eng. (analytics)</th>
<th>Mobile Eng. (analytics)</th>
<th>Contribution (comments)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Parasite Farm</td>
<td>91.7%</td>
<td>86.6%</td>
<td>31.4%</td>
<td>23.7%</td>
<td>1.28%</td>
<td>0.25%</td>
</tr>
<tr>
<td>LillyBot 2.0</td>
<td>50.0%</td>
<td>60.8%</td>
<td>10.5%</td>
<td>10.0%</td>
<td>0.97%</td>
<td>0.17%</td>
</tr>
<tr>
<td>Ritual Machines</td>
<td>16.7%</td>
<td>47.0%</td>
<td>4.3%</td>
<td>5.4%</td>
<td>0.38%</td>
<td>0.05%</td>
</tr>
<tr>
<td>Dust Matter(s)</td>
<td>33.3%</td>
<td>61.7%</td>
<td>10.9%</td>
<td>7.9%</td>
<td>0.38%</td>
<td>0.12%</td>
</tr>
</tbody>
</table>

Correlation r  
- 0.972  
- 0.967  
- 0.978  
- 0.936  
- 0.982

t-value  
- 5.802  
- 5.387  
- 6.675  
- 3.755  
- 7.315

p-value  
- 0.0011  
- 0.0017  
- 0.0005  
- 0.0094  
- 0.0003

Table 39: Correlation between attention potential and measured attention and engagement

While the correlation is based on only four data points per series and does not imply causality, it suggests that the attention potential of SOL installations is indicative of the relative levels of attention and engagement they receive.

Future research might therefore use the attention potential of placement options as an additional vector to inform object selection and local positioning. It might also be used as a tool to scope expectations about attention and engagement, and to inform mitigating design choices, e.g. using a more luminous display or a more conspicuous casing to compensate for the low attention potential of a placement.
8.5.5.3 Design implications for the mobile application

While the mobile application is outside the main focus of the research, the findings give some hints at how it was used and understood by visitors (see 8.5.4.3.3). Of particular interest in this context is the content rating system, which has been integrated into the mobile application to incentivise high-quality contributions and thereby improve the overall quality of submitted content in a transparent and democratic way. Analytics data showing that the rating mechanism was used only a few times indicates that it might not be sufficiently discoverable in the current design. Future iterations should aim to make the rating system easier to discover and investigate if this increases its use.

8.5.6 Reflection on collaboration and research environment

Based on the experiences in the first field trial (see 8.3.6), the investigator made an effort in this second field trial to improve communication with SGD and allocate more time to be physically present in the gallery. This included communicating more regularly with SGD staff, switching to individual members’ preferred communication channels, keeping involved staff up to date on development and providing detailed information about casing requirements, together with models for illustration. These materials helped technical staff at SGD to develop their own ideas for a casing, which turned out to be both simpler and better than the suggested design. Multiple visits to SGD enabled the researcher to spend more time in the gallery, build rapport with staff and student mediators, informally discuss how SOLs could be used to engage visitors and support social interpretation, help with the installation, monitoring and maintenance of SOLs in the gallery space, and carry out observations and interviews during the evaluation period.

While these measures helped to create a better understanding between the investigator and museum staff and resulted in a better casing design and more awareness about research aspects, they could not mitigate fundamental differences in priorities. Several aspects of the collaboration illustrate how curatorial practices, constraints and considerations take precedence over research aspects in a live gallery environment:

- Fields trials need to fit with the gallery's programming calendar and require the support of everyone involved. These two factors led to several delays in the second field trial, first due to development delays missing the exhibition deadline, then due to objections by the curator of the following exhibition to use SOLs in the gallery, and finally due to the next exhibition being deemed unsuitable for the field trial, leading to a total delay of nine months until the evaluation got underway.

- Field trials must conform with the institutions practices and culture. Based on evidence from literature and findings from the first field trial suggesting that a lack of framing can be a barrier to engagement, a flyer was developed explaining the use of SOLs in the gallery. However, the flyer was ultimately not used as it did not fit not fit with standard practice at SGD to not provide instructions with interactive exhibits and instead rely on visitors' curiosity to try things out.
• Field trials must be able to cope with changes and pragmatic choices. While preliminary discussions with curators identified a subset of exhibits most suitable for social interpretation by visitors, the actual selection changed last minute based on layout considerations in the gallery space, available mounting options and the ability to obtain artists’ consent to install a SOL next to their work.

• Field trials take part in a larger context with its own agenda and priorities. One SOL had to be run on battery instead of mains power as there was no close-by power socket available. While SGD staff were briefed on how to monitor, swap and restart SOLs, and were sent automated email notifications at critically low battery levels, the installed SOL ran out of battery several times as staff prioritised their individual core responsibilities.

Together, these experiences illustrate that while museums might welcome research taking place in their galleries, their priority is to ensure a smooth running of normal operations and providing a first-class experience to visitors. A key implication for field trials is that they must be flexible enough to cope with unforeseen changes and accept that research designs cannot always be fully implemented if they conflict with contextual constraints, curatorial considerations or institutional practices.

8.5.7 Limitations

In line with calls in the literature that ubicomp technologies should be evaluated in realistic environments (Abowd and Mynatt, 2000; Hazlewood and Coyle, 2009; Ju and Sirkin, 2010; Abowd, 2012), the emphasis of this second evaluation study was again on ecological validity, as reflected in the detailed description of the gallery deployment, the use of non-obtrusive data collection methods and, for interviews, the ad-hoc convenience sampling.

Carrying out the research in a live gallery environment limits control by subordinating it to the museum’s constraints, practices and natural visitor flow. In addition, the wide scope of the evaluation, ranging from attraction and engagement to interaction and mental models of SOLs, as well as the limited timeframe in which it is carried out, further constrain the research design. Limitations relating to one or more of these factors include:

• The study does not involve clear A/B testing as the evaluated designs vary in more than one parameter as well as their exact implementation. While this decreases internal validity, it increases external validity by exploring design variations in different combinations, making it more likely that findings can be generalised beyond specific configurations.

• The study involves a large number of observations, however, it can be difficult to judge from observations only whether someone looks at and actually notices a SOL. While this introduces an error margin for observed attention rates, it should not affect the comparison with traditional object labels, as the same problem applies.

• Engagement rates are based on user journeys and potential encounters, both of which are approximations. In order to avoid overstating engagement rates,
conservative values were used, i.e. minimum values for user journeys and maximum values for potential encounters. The methodology section describes in detail how the number of user journeys (see 8.5.3.2.3) and potential encounters (see 8.5.3.2.4) were calculated to put findings into context and invite scrutiny.

- The low levels of mobile engagement and content contribution rates against the large number of potential encounters makes conventional thresholds for statistical significance problematic, e.g. contribution rates for designs with a question are nearly three times higher than for alternative designs but not statistically significant \( p = 0.096 \) at the conventional 0.05 level.

- The “attention potential” of SOL installations (see 8.5.2.1) is based on a subset of placement-related factors identified by Bitgood (2009a, 2009b) to affect visitors’ attention in museums, but is likely to be influenced by many other factors. The strong and significant correlation with actual attention and engagement rates is based on only four installations and does not imply causality. More research is needed to identify additional factors influencing attention potential and to assess the utility of the concept in predicting actual attention and engagement with SOLs.

With regard to transferability, many findings of this evaluation are general enough to be applicable to other contexts and environments. While emerging from a study investigating SOLs in particular, they relate to design aspects equally relevant to other display concepts. This includes findings relating to casings, display technologies, touch screen and mobile interaction, information design, personalisation and placement of displays.

### 8.5.8 Conclusions

This section has described the background, methodology, findings and design implications of a second empirical evaluation of SOLs at SGD. Unlike the first evaluation (see 8.3), which had an exploratory character and evaluated one specific design based on two installations, the present study involved four installations and a range of designs that varied in user interface and interaction capabilities to increase engagement, integrate SOLs with the exhibition and focus visitors’ interpretation efforts.

Reflecting this complexity, the evaluation used a range of data sets including observations in the gallery, visitor interviews, visitor numbers based on automatic counters and detailed analytics data. The latter required instrumentation of the SOL prototype to collect and report analytics data, additional functionality in the backend to monitor SOLs and remotely trigger design changes, and the development of a data analytics and visualisation tool to view and interrogate analytics data in real-time. Together with the configuration options introduced in the previous prototype, these additions led to a highly adaptable system that supports research in authentic settings based on real-time engagement and interaction data as called for in Hazlewood and Coyle (2009).

One research question in this study was how much attention SOLs attract and how this compares to conventional object labels. The findings show that the evaluated designs attracted similar levels of attention as traditional object labels, suggesting that the current
prototype strikes a good balance between attracting attention and not distracting from the exhibit. While visitor interviews mention active colour displays and casings that stand out from the exhibition design as a way to increase attention to SOLs, analytics data and observations suggest that in fact placement, in the local context of the exhibit and in the global context of the gallery, has the biggest impact on attention and engagement rates.

A second research question was how different screen designs impact on engagement with SOLs:

- The results confirm that designs with direct interaction content browsing generate more engagement than designs without content browsing. However, most of that engagement is limited to direct interaction on the SOL touch screen, refuting the assumption that reading comments on the situated display stimulates content contributions and leads to more mobile interaction. Instead, the findings suggest that mobile interaction is largely independent from touch screen interaction and seen by visitors as an alternative way to engage with SOLs rather than a continuation or escalation of direct touch interaction in order to access additional functionality available on the mobile such as adding or rating comments.

- The results do not support the assumption that posing a question on the SOL screen increases engagement by generating interest and framing visitors’ interpretation. Designs with a question generated less direct engagement (and therefore less overall engagement) than designs without a question. They had, however, higher mobile engagement and contribution rates. While these were not statistically significant, the latter in particular was noticeable and calls for further research investigating questions as a tool to encourage more active participation where visitors submit comments of their own rather than only browsing others’ comments.

- The results refute the assumption that displaying an exhibit-specific icon on the SOL, which is also shown on the traditional object label and in other exhibition materials, increases engagement by helping visitors to associate SOLs with the exhibit and understand them as an alternative to object labels. Designs with an exhibit-specific icon had consistently lower engagement and contribution rates, suggesting that calls to action, as shown in alternative designs, are more effective in encouraging engagement.

A third research question concerned visitors’ user experience of SOLs. The results confirm assumptions that visitors prefer direct touch interaction to mobile interaction and that content browsing in particular is very popular. Interviews suggest that many visitors are initially unclear about the purpose of SOLs and expect them to be information devices rather than a platform for visitor comments. Some visitors were not aware that SOLs are interactive as they did not recognise the e-ink display as a dynamic touch screen. Self-reported barriers to engagement and content contribution are manifold, ranging from a general predisposition not to engage with interactive objects in the gallery or not to submit comments, to a lack of interest, technical issues, lack of supporting information and a wide
range of other reasons, with design aspects seemingly playing only a minor role. The majority of visitors who had engaged with SOLs found them easy to use, thought it was worth using them and would use them again, however, the findings suggest that many aspects of the current design can be further improved. For the mobile application, this includes making functionality more discoverable, and for SOLs this includes personalising the experience with the situated display, for instance by detecting touch patterns that indicate boredom or frustration and reacting accordingly, or by unobtrusively identifying users and adapting the interface based on their previous interaction.

An unplanned but promising outcome of the study has been the conceptualisation of the "attention potential" of potential placements and a related tool to quantify that potential by rating placement-related characteristics identified in Bitgood (2009a, 2009b). Although the findings are based on only four SOL installations, they suggest a strong and significant correlation between attention potential and actual attention and engagement rates, suggesting the tool could be useful to identify suitable placements, scope expectations for engagement levels and inform design choices to mitigate low attention potentials. Further research is needed to confirm these findings and generalise the developed tool.

Collaborating with SGD staff and carrying out the field trial in a live gallery environment meant that not all aspects of the research design could be fully implemented. While this is not ideal in an iterative research approach, which relies on applying and testing learning in successive cycles, it is a small price to pay given the clear benefits of evaluating SOL designs in realistic environments with regard to ecological validity and discovering unforeseen problems that would be difficult to identify in lab studies.
9  Design recommendations

A key research question in this thesis is how SOLs should be designed and integrated with museum environments (RQ3). Relevant aspects in this context include how to attract visitors’ attention and encourage engagement without distracting from the exhibit, how to enable mobile interaction and balance functionality between mobile device and the in-situ display, and how to integrate SOLs with the physical, technical, information and interaction environment in which they are deployed.

In order to answer these questions in a comprehensive and systematic way, this section is structured after the ten high-level design aspects identified in the design space analysis (Chapter 4) and draws on findings from the literature review (Chapter 2), museum visitor survey (Chapter 5), user and scenario modelling (Chapter 6), expert interviews (Chapter 7) and prototype design and evaluation activities (Chapter 8). It formulates design recommendations for salient features of each design aspect and discusses implementation examples and related evidence.

<table>
<thead>
<tr>
<th>FL</th>
<th>Findings from the literature review</th>
</tr>
</thead>
<tbody>
<tr>
<td>FV</td>
<td>Findings from visitor interviews</td>
</tr>
<tr>
<td>FS</td>
<td>Findings from scenarios</td>
</tr>
<tr>
<td>FX</td>
<td>Findings from expert interviews</td>
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<tr>
<td>FP</td>
<td>Findings from early prototyping</td>
</tr>
<tr>
<td>FT</td>
<td>Findings from user testing</td>
</tr>
<tr>
<td>FC</td>
<td>Findings from co-design sessions</td>
</tr>
</tbody>
</table>

*Table 40: Key to findings from research activities*

The design and deployment recommendations reference findings identified throughout the research, using the keys in Table 40. An index of all formative findings, including identified requirements, user preferences and design guidelines from the literature, is provided in Appendix A, together with relevant page numbers where they are discussed in context.

Related implementation and deployment aspects of the evaluated SOL prototypes are discussed where available to provide practical examples of how the recommendations can be applied in realistic settings. Implementation examples often reference specific SOL prototypes, which are described in detail in Appendix B.

Related evidence, emerging from the present research or referenced in the literature, is discussed to support the design recommendations. Evidence typically references section numbers in this thesis where related findings are discussed in context.
9.1 Openness

9.1.1 Content creation

**Recommendations**

A fundamental idea of SOLs is the in-situ annotation of physical objects and places. While museum visitors value the immediacy of commenting at the point where they experience an exhibit (FV2), they also welcome the option to remotely comment in their own time when at home (FL47, FV2). SOLs can support both in-situ and remote annotation, however, given their primary purpose as an in-gallery commenting system, the design should focus in first place on in-situ commenting (FX11).

**Implementation Example**

Technically, there is no requirement for users to be co-located with the SOL prototypes in order to browse or submit comments via their mobile, however, in both evaluation studies the necessary connection information was available only on SOLs, which de-facto required users to be present at the exhibit in order to connect their mobile. Museums might additionally make connection information available elsewhere, e.g. on object or exhibition webpages, and thereby enable "untethered" (Meramovic et al., 2013) access.

**Evidence**

Interviews with museum visitors indicate that they would like to have the option to comment both directly at the exhibit and remotely from home (see 5.3.3). Museum experts like the idea of in-situ and remote commenting bridging the gallery- and online-experience of an exhibition, however, they emphasise that this is not a key requirement and that SOLs should focus in first place on in-situ commenting (see 7.3.3).

9.1.2 Content syndication

**Recommendations**

While SOLs focus specifically on the in-situ annotation of exhibits in the gallery space, submitted comments and ratings might also be of interest in other contexts. For this purpose, SOLs should make content available in open, commonly used formats that have broad developer support (FS41, FX17). As contexts might be differently scoped, it should be possible to filter submitted content by organisation, exhibition and exhibit (FX18).

- 259 -
Implementation example

SOL prototypes 5+ provide customisable feeds of submitted content that can be consumed in a variety of contexts and platforms. Feeds use the widely supported and W3C endorsed RSS 2.0 (Really Simple Syndication)\(^{30}\) format and can be scoped via parameters.

| Endpoint: | http://itrg.brighton.ac.uk/ubinote/rss.php |
| Parameters: | hid = Host ID | cid = Campaign or Exhibition ID | oid = Object ID |

Evidence

Museum experts point out that user-generated content should be available for export in open, simple and well-supported formats such as RSS or JSON (7.3.5), for instance to integrate into exhibition or object pages on the website (ibid). With regard to the actual implementation, the RSS feed in prototypes 5+ was welcomed by SGD staff but not integrated into exhibition websites as in both field trials SOLs were only installed during the second half of the exhibition.

9.1.3 Social media integration

Recommendations

The two main arguments for integrating SOLs with social media relate to marketing and user experience. From a marketing perspective, it is beneficial for museums if visitors share their experience in the gallery with a wider audience and thereby help to promote an exhibition and increase visitor numbers (FX9). From a user experience perspective, it integrates commenting with visitors’ personal communication habits and platforms (FV6, FV7), thereby removing technological barriers and streamlining engagement. Museum experts point out that social media integration should be optional and not complicate the interaction (FX10). Visitors should not be forced to link to their online profile (FV8) and SOLs should avoid dependencies on third-party logins (FX8). With regard to in-bound and out-bound social media integration, preference should be given to the former as it better integrates with visitors’ communication habits (FV7).

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\(^{30}\) RSS 2.0 Specification. Available https://validator.w3.org/feed/docs/rss2.html
**Implementation Example**

SOL prototype 5 implemented out-bound social media integration that enabled visitors browsing comments on their mobile to post (forward) them to various social media channels. The option was made available in a context menu together with other functionality such as emailing a comment to someone or flagging it for moderation. By contrast, SOL prototype 7 implemented in-bound social media integration where visitors can submit comments to SOLs by posting a message on Twitter using an exhibit-specific #hashtag.

**Evidence**

Many museum visitors value the inherent qualities of social media such as being interactive, affording open discourse, sharing and broadcasting, and integrating with personal communication habits (see 5.3.3). Museum professionals acknowledge the usefulness of social media integration but caution that it must not impact on the user experience (see 7.3.3). There is no evidence that out-bound social media functionality in SOL prototype 5 was used. In-bound social media functionality in SOL prototype 7 was used in only two instances, however, due to the overall low contribution rate this represents nearly 10% of all contributions (see 8.5.4.2.2 and 8.5.4.3.2). Demographics data from visitor interviews shows that overall only 27% of participants use Twitter on their mobile (see 8.5.3.2.2), suggesting that support for additional social media platforms would increase the number of potential users.

### 9.1.4 Content conservation

**Recommendations**

Preserving submitted content adds to the openness of a system by making contributions available even after an exhibition closes and thereby enabling as yet unknown future uses. Submitted content and interaction statistics should be archived together with an exhibition (FX12) and become part of the exhibit's profile (FL45). The data should be stored in an open, standardised and future-proof format (FL46, FX12).

**Implementation Example**

User-generated content and interaction statistics are stored by the SOL backend in a widely supported, open source, relational database (MySQL). Both are linked to object IDs and therefore to the physical objects and related digital resources. There are currently no technical measures or policies to limit the duration for which the data is stored.

**Evidence**

Many museum visitors think that electronically submitted comments should be kept indefinitely (see 5.3.7). While some museum experts question the usefulness of submitted content once the exhibition is over, others think it can help to document engagement with an exhibition and should be archived indefinitely (see 7.3.4).
9.1.5 Transparency

Recommendations

Transparency creates trust and understanding, which in turn fosters a feeling of control among users (FL15) and can lead to more and better informed engagement. Transparency can be improved by clarifying the purpose of SOLs in the gallery, explaining the interaction with SOLs and informing visitors about the organisation's practices and policies around submitted content, in particular with respect to access, readership, moderation, conservation, remediation, intellectual property and potential commercialisation (FX13, FV4, FV9, FV14, FV15, FV17). This information should be provided in an unobtrusive way that does not complicate the interaction or create a barrier to participation (FV16, FX14).

Implementation Example

There is currently no notice of terms in the mobile application or on the SOL display in the evaluated prototypes. While a flyer was developed for Home\Sick explaining the purpose, interaction and content policies around SOLs (see 8.5.2.2), it was not actually distributed. Instead, student mediators, who are present at all times at SGD to engage with visitors, were briefed on these aspects and ready to answer any questions about SOLs (ibid).

Evidence

Most visitors have only vague ideas how submitted content might be handled by museums and would like to be informed about this aspect in an unobtrusive way (see 5.3.5 to 5.3.8). Museum professionals generally agree that visitors should be informed but advocate lightweight approaches that do not create a barrier to participation (see 7.3.4). A lack of information about the context, purpose and interaction with SOLs was identified in both field trials as a barrier to engagement (see 8.3.4.2 and 8.5.4.4.4), indicating that the passive approach taken at Fail Better and Home\Sick, which depends on visitors asking staff or student mediators about SOLs, is not sufficient in making the experience transparent.

9.2 Plasticity

9.2.1 Customisation

Recommendations

Museum staff want detailed control over the user interface design and terminology on SOLs (FL25). Of particular interest is the ability to display exhibit-specific prompts or questions that can encourage engagement and scaffold visitors' interpretation (FL34). SOLs should enable administrators to dynamically change design aspects in order to evaluate and customise the user interface for specific target environments and exhibits (FL43, FS31, FP6).

31 Aspects related to plasticity and ad-hoc deployment are also discussed in Winter (2014b)
Implementation Example

SOL prototypes 4+ support a wide range of designs that can be selected in configuration mode. Exhibit-specific images, prompts or questions can be added and edited in the administration panel. In addition, prototype 7 gives administrators dynamic control over the terminology on the SOLs (e.g. when collecting "comments", "ideas", "thoughts", "fails", "stories", etc.) and supports scheduled changes to the user interface to support evaluation in the field (together with relevant analytics). Prototype 7 also supports exhibition-specific mobile stylesheets to better integrate the mobile experience with the exhibition design.

Evidence

Empirical studies found that the terminology, colouring and layout of the user interface influence commenting behaviour (see 2.3.3.2). In order to adapt these design aspects in accordance with guidelines on information presentation (see 2.4.3), curators need detailed control over the SOL user interface and the ability to refine prompts and questions (see 2.4.2). The customisation options in SOL prototypes 4+ were not formally evaluated (see 8.2.4), however, the option to quickly change user interface parameters proved useful when discussing possible designs for Fail Better with museum staff (8.3.2.4). The capability in prototype 7 to automatically and remotely change design parameters facilitated the evaluation of design variations in Home\Sick (see 8.5.3.1).

9.2.2 Configuration

Recommendations

SOLs should have a dedicated configuration mode (FS28) to register them to an exhibit and select suitable technical and design options. To support this process, the configuration screen should show relevant status information such as battery level and wireless signal strength (FS29, FP15) and provide functionality to manage wireless connections (FS37). The configuration mode should be password protected and implemented in a way that minimises the chance of accidental activation by museum visitors (FS36).

Implementation Example

SOLs start up in configuration mode, which offers functionality to specify an object ID, select a screen design and networking mode, turn logging on or off, view logs and manage wireless connections. The configuration screen displays the battery level and wireless status and signal strength. When in display mode, the configuration mode can be activated via a hidden button in the top right corner of the screen, which produces a password dialogue that leads to the configuration mode if the entered password is correct or disappears otherwise. The password dialogue times out after 10 seconds if no password is entered.

Evidence

The need for a dedicated, password-protected configuration mode emerged from the scenario-based design process (see 6.5, Scenario 4). Interviews suggest that SGD staff found
the admin interface easy to understand and had no problems connecting and setting up the SOLs (see 8.3.4.3). The ease of use and low maintenance were key reasons for SGD staff to support future deployments of SOLs in the gallery (ibid).

9.2.3 Deployment

Recommendations

In order to adapt to different technical environments, SOLs need to support a range of networking and power options (FL20, FP1). In particular, this includes supporting mobile connections via local and mobile data networks (FP11) and being able to run on mains power and battery (FS30). With regard to integration with the physical environment, SOLs should support a range of displays types, sizes and casings to adapt to specific lighting conditions, exhibition designs and exhibits (FS25, FX25).

Implementation Example

The evaluated SOL prototypes support a range of communication models (see Appendix C), which can be activated in the configuration panel. They support mains and battery powered operation and automatically fall back to battery on mains power failure, lasting between 12 and 96 hours depending on the communication model. While SOL prototypes 1 to 3 use a variety of displays, prototypes 4+ all use the same type of e-ink display. Display units are independent from the casing in all developed prototypes.

Evidence

Network connectivity and power supply are mentioned in the literature as key problems when deploying public displays (see 2.2.4). The ability to wirelessly connect to WiFi and 3G networks and to support mains power while falling back on battery-powered operation proved critical during early prototyping (see 8.2.3) and in field trials at Fail Better (see 8.3.2.2) and Home\Sick (see 8.5.2.2). Both field trials involved custom casings produced by SGD, making it a fundamental requirement for SOLs to separate display and casing (see 8.3.2.1 and 8.5.2.1).

9.2.4 Scalability

Recommendations

In order to deploy SOLs at short notice and at scale, administrators need suitable tools to dynamically create object IDs and digital resources for exhibits (FS26). Object IDs should be unique and inexhaustible (FL8). Combined with functionality for dynamic object registration (FS27), this enables ad-hoc deployment and allows for displays to be swapped out in case of low battery or a technical fault.
Chapter 9 Design recommendations

Implementation Example

The SOL administration panel provides functionality to create unique object IDs and related digital resources such as an image, a prompt or question and custom terminology (e.g. submit a "comment", "thought", "fail", "idea", etc.). The administration panel is based on Web technologies and uses responsive design principles to support both desktop and mobile use in the gallery. All SOL prototypes support dynamic registration via an object ID.

Evidence

The need for dynamic registration and creation of digital IDs emerged from the scenario-based design process (see 6.5, Scenario 4) and is intrinsically linked to SOLs as a generic platform suitable for low-cost ad-hoc deployments discussed in Winter (2014b). The functionality proved essential in evaluation studies as in both field trials the selection of target exhibits was only finalised on the day of deployment after reviewing installation options in the gallery space (see 8.3.2 and 8.5.2).

9.3 Interrogability

9.3.1 System status

Recommendations

SOLs should support in-situ and remote monitoring. For in-situ monitoring, SOLs should display unobtrusive but recognisable status indicators when running low on battery or losing network connection (FS29, FP15). For remote monitoring, SOLs should report status information to the backend (FS32, FS33), which should provide an administration panel with status information about all deployed SOLs (FS35, FS39).

Implementation Example

SOL prototypes 5+ show notifications on the in-situ display when running low on battery or losing network connection. In addition, prototype 7 reports status information to the backend and displays the information in an administration panel (see 8.5.2.2, Figure 59).

Evidence

The requirement for SOLs to display and report status information emerged from the scenario-based design process (see 6.5, Scenario 4), interviews with museum professionals (see 7.3.6) and early prototyping (see 8.2.4). The need to support remote monitoring and to use commonly recognisable status indicators are based on the experience with SOL prototype 5 during Fail Better, where the deployed SOLs ran out of battery in several instances (see 8.3.2.2) as museum staff had not noticed the indicators and would not have known what they mean if they had noticed them (see 8.3.3.3). As a consequence, SOL prototype 7 has more recognisable indicators and in addition to in-gallery monitoring supports remote monitoring from desktop and mobile devices via an administration panel.
Chapter 9 Design recommendations

The changes did not prevent one SOL running out of battery at Home\Sick (see 8.5.2.3), however, they enabled the researcher to remotely monitor uptimes to inform the data analysis (see 8.5.3.2.4).

9.3.2 Analytics data

Recommendations

SOLs should collect detailed analytics data about users' interaction (FL54) and report them to the backend, which should provide suitable tools to visualise and analyse the data in real-time (FL42). In combination with features relating to Plasticity (see 9.2) this enables museum staff to evaluate deployed SOLs on the fly and optimise them according to their educational goals.

Implementation Example

SOL prototype 7 reports detailed interaction data to the backend (see 8.5.3.2.3) and provides an analytics visualisation tool that enables museum staff and researchers to analyse the data in real-time (see 8.5.3.3).

Evidence

The need to evaluate ubicomp technologies in realistic settings is widely acknowledged in the literature and integrating evaluation aspects into the design of public displays has been identified as a sustainable way to unobtrusively detect how users perceive and react to them (see 2.5.1). Interaction data from SOLs, analysed with the developed analytics and visualisation tool (see 8.5.3.3), substantially contributed to the evaluation of SOL design aspects (see 8.5.4.2 and 8.5.4.3).

9.4 Ease of engagement

9.4.1 Streamline engagement

Recommendations

SOLs should streamline engagement and avoid interruptions (FL4, FV1). This includes not forcing users to register or login (FL24, FL50, FX7), install an application (FL49, FP12) or provide additional information when submitting comments (FV3, FX5, FX6) and not showing unnecessary conformation screens after submission (FP8). Where user identification is necessary, e.g. to enable editing of own comments (FL23), it should be automatic and anonymous (FL24, FS13). For users identified in this way, relevant entry fields should be pre-populated with previously volunteered information (FS11).

Implementation Example

In addition to direct engagement on the situated touchscreen in SOL prototype 7, both evaluated prototypes support engagement via a mobile Web application that does not
require installation on the user's device. The application uses a combination of client-side and server-side technologies to automatically identify users and assign editing rights for submitted content. Users can optionally provide a screen name when posting comments, which is then pre-populated in repeat visits.

Evidence

The requirement to streamline engagement is supported by literature (Kules et al., 2004; Alt et al., 2014), visitor interviews (see 5.3.3 and 8.5.4.4.3), interviews with museum professionals (7.3.2) and informal evaluations during early prototyping (see 8.2.2 and 8.2.3). While some design aspects, typically relating to content ownership (Fisk, 2006) and content quality (Alt et al., 2014), depend on user identification, findings from scenario-based design (see 6.5, Scenario 1) and interviews with museum professionals (7.3.2) suggest that automatic user identification is most appropriate in this context.

9.4.2 Peripheral participation

Recommendations

As different users participate in different ways and some might find it difficult to formulate and submit text comments, SOLs should support alternative contribution modes such as ratings that do not require actual content creation (FL31, FL33). SOLs should collect and display statistics about such interactions to reward peripheral participation (FL30, FL32).

Implementation Example

SOL prototypes 5+ support star ratings for objects as an alternative to comments. In addition, SOL prototype 7 enables users to rate other visitors' comments via a binary thumbs up/down mechanism and thereby influence their ranking and visibility. These ratings are shown below each comment on both the SOL and the mobile application.

Evidence

The recommendation to address participation inequality with alternative contribution modes and related rewards is supported by literature (see 2.3.3.3). With regard to the implementation in SOL prototype 7, analytics data suggests that many visitors assumed the thumbs up/down icons on the SOL touch screen to be interactive and would have rated comments if they actually were (see 8.5.4.3.1). By contrast, the rating functionality in the mobile application was little used (see 8.5.4.3.3), suggesting discoverability problems.

9.4.3 Supporting information

Recommendations

SOLs should display information on how to connect a mobile device (FS1). Web addresses should use traditional, well-known top-level domains (FC6) and be displayed without a
scheme (FC7). Connection information should be available in all screens where mobile interaction is anticipated (FT2).

**Implementation Example**

While both evaluated SOL prototypes show connection information for mobile interaction, SOL prototype 7 has a dedicated help screen that is activated when users touch otherwise not interactive screen elements.

**Evidence**

The requirement to show connection information emerged from the scenario-based design process (see 6.5, Scenario 1) while recommendations on the presentation of URLs are based on findings from the formative user testing (see 8.4.4.4 and 8.4.4.5). User testing also found a need for having connection information available in both browse and help screens (see 8.4.3.3, OT6). With regard to help information, observations during Home\Sick show that mobile interaction is largely independent of direct interaction on the SOL touch screen (see 8.5.4.3.2), suggesting that detailed instructions on how to connect a mobile device might not be needed and that help information should rather focus on higher-level aspects that otherwise might not reach visitors (see 8.5.2.2 and 8.5.4.4.4).

### 9.4.4 Supporting environment

**Recommendations**

SOLs should be framed in a comprehensive organisational effort to promote mobile technologies and a social visitor experience (FL52) through an appropriate technical infrastructure and relevant policies that create a participatory atmosphere.

**Implementation Example**

SGD cultivates an open, participatory atmosphere in the gallery with a wide range of analogue and digital engagement opportunities, free access to wireless network and no restrictions on mobile phone use in the gallery space (see 8.3.2.5 and 8.5.2.5).

**Evidence**

The requirement for a supporting environment that facilitates mobile engagement is supported by literature (see 2.4.5). With regard to the implementation example, visitor interviews suggest that 95% of visitors think that mobile phone use is welcome at SGD (see 8.5.4.4.4). While 16% of visitors say that using a mobile phone would ruin their gallery experience, this was not mentioned as a barrier to engagement (ibid).
9.4.5  Ergonomy

Recommendations
SOLs should be placed at a suitable height (FL17) that complies with health and safety regulations and accessibility legislation (FL18) and with enough empty space around them for comfortable interaction (FL19).

Implementation Example
During the field trial at Home\Sick SOL1 was installed at a height well suited for touch-screen and mobile interaction and with much empty space around it, while SOLs 2-4 were installed at a lower height that required most grown-ups to bend down to interact and in some cases had little space around them for comfortable interaction (see 8.5.2.1).

Evidence
The need to consider ergonomic aspects when placing displays affording direct or mobile interaction is discussed in the literature (see 2.2.4). With regard to the deployment in Home\Sick, the need to bend down to interact with a SOL was mentioned as a barrier to engagement in visitor interviews (see 8.5.4.4.4).

9.5  Interaction modality

9.5.1  Interaction modes and technologies

Recommendations
SOLs should support multiple interaction modes and methods that cater for different contexts and user preferences (FL11, FP7, FT3). In order to cater for visitors with and without mobile devices or data plans, SOLs should support direct interaction on the situated display and mobile interaction via wireless and mobile data networks (FS17, FP11). Mobile interaction should not rely on specific technologies, applications or social network memberships (FT3, FS2, FX8) and connection information should be provided in different formats, including human-readable (FL9).

Implementation Example
SOL prototypes 5+ support mobile interaction via NFC, QR codes and human-readable URLs. Prototype 7 extends this range with direct interaction on the SOL touch screen and content contributions via Twitter. Both prototypes support mobile interaction via WiFi and mobile networks (see Appendix C). The mobile application is built on open Web technologies that are broadly supported across different mobile devices.
Evidence

The recommendations emerged from the scenario-based design process (see 6.5, Scenarios 1 and 2) and are supported by literature (see 2.2.3.3), expert interviews (7.3.2) and findings from early prototyping (see 8.2.2 and 8.2.3) and user testing (see 8.4.3.1). Empirical evaluations show that support for direct interaction on the SOL touch screen dramatically widened participation (see 8.5.4.2) compared to mobile interaction only (see 8.3.4.1). Observations and analytics data show that mobile interaction is largely de-coupled from touch screen interaction and perceived by visitors as an alternative to, rather than a continuation of, direct interaction (see 8.5.4.3.2). All supported mobile interaction methods were used during the evaluation at HomeSick (ibid), proving demand. The fact that there is little overlap between direct and mobile interaction, that not a single visitor used more than one mobile connection method (ibid) and that technical issues continue to be a barrier to participation (see 8.3.4.2 and 8.5.4.4.4) suggest that visitors' technical capabilities and preferences constrain engagement and that support for additional connection methods can increase participation.

9.5.2 Distribution of functionality

Recommendations

Where appropriate, functionality should be offered redundantly in different interaction modes. Where this is not possible or impractical due to technical constraints of one interaction mode versus another (e.g. lack of user identification in direct touchscreen interaction), common base functionality should be offered in both interaction modes (FS4).

Implementation Example

SOL Prototype 7 offers content browsing on both the situated touch screen and the mobile device. Other functionality such as creating, editing, rating and flagging comments are only available in the mobile application as they require user identification, which is not currently supported on the SOL display.

Evidence

The recommendations emerged from the scenario-based design process (see 6.5, Scenario 1) and are supported by evaluation results showing that users tend to stick to their preferred interaction mode and do not switch between modes to access additional functionality (see 8.5.4.3.2). Analytics data suggests that many visitors tried to rate comments on the SOL touch screen (see 8.5.4.3.1), however, the functionality was only implemented on the mobile and therefore rarely used.
9.5.3 Multi-user support

Recommendations
SOLS should support multi-user scenarios, e.g. enable one user to connect their mobile device while another interacts with the in-situ display, and enable multiple mobile devices to be connected at the same time (FL5, FS16).

Implementation Example
While direct interaction with the SOL touchscreen (prototype 7) is typically limited to a single user, this does not prevent a second user to simultaneously interact with the SOL on their mobile device. SOLs and the related mobile application inherently support multi-user scenarios due to their client-server architecture.

Evidence
The requirement for multi-user support emerged from the literature (see 2.2.2.3) and scenario-based design process (see 6.5, Scenario 2). Observations in the gallery show that for visitors attending in groups it is not uncommon for one visitor to operate the SOL touchscreen while the other looks over her/his shoulder or alternatively scans the NFC tag and then browses comments in parallel on his/her mobile device (see 8.5.4.3.2).

9.5.4 Social acceptance

Recommendations
SOLS should avoid social embarrassment for users (FL7). While this relates in first place to unconventional interaction modes, a related concern is that the placement of SOLs should be appropriate for the interaction mode and not cause unnecessary exposure (FL14).

Implementation Example
SOLS do not use unconventional interaction modes such as voice or embodied interaction, and they provide alternative connection methods such as manual URL input for people who are insecure about QR codes or NFC. The placement of SOLs in both evaluation studies did not unduly expose visitors (see 8.3.2.1 and 8.5.2.1).

Evidence
The recommendations are supported by literature (see 2.2.2.3 and 2.2.3.4). With regard to the implementation of this recommendation in Fail Better and Home\Sick, visitors did not mention any barriers to engagement relating to social embarrassment (see 8.3.4.2 and 8.5.4.4.4). With regard to mobile interaction in particular, interviews suggest that most visitors find mobile phone use in galleries acceptable (see 8.5.4.4.4).
9.6 User control

9.6.1 Personal information

Recommendations
SOLs should not force users to identify themselves or to link to their online profile (FV8). When submitting content, any personal information should be optional (FV3, FX5, FX6).

Implementation Example
SOL prototypes 4+ use technical means to anonymously identify mobile users and provide an optional name field when submitting comments. If users do provide a name, it is pre-populated on subsequent visits.

Evidence
The recommendations are based on findings from the museum visitor survey (see 5.3.3 and 5.3.8) and interviews with museum professionals (see 7.3.2). Many visitors would not be willing to provide a name with their comment and would not be interested to know the commenter’s name when reading a comment (see 5.3.4). Furthermore, for most visitors association with a name is the most critical aspect when judging the acceptability of comment reuse scenarios (see 5.3.8).

9.6.2 Format and topic

Recommendations
Users should be given control over the topic and format of their contribution (FV3) and not be forced to fill in required fields with additional information (FV3, FX5, FX6).

Implementation Example
While the evaluated SOL prototypes have a provision for administrators to pose a question and thereby set a topic, the content contribution screen in the mobile application shows a single generic text field to write a comment rather than forcing users to fill in a series of specific fields with questions.

Evidence
The recommendations are based on findings from the museum visitor survey, where participants expressed a preference for free-format commenting mechanisms and for choosing their own topic (see 5.3.3). Evaluation results showing that designs with a question had overall lower engagement rates but higher contribution rates (see 8.5.4.2.2) suggest that the combination of proposing a topic but not enforcing it is an acceptable compromise between museums’ posing a question in order to encourage engagement (see 2.4.2) and visitors having control over the format and topic of their contribution.
9.6.3 Submitted content

Recommendations

SOLs should give visitors control over their content (FL37, FV18) by enabling them to edit comments after submission (FS14).

Implementation Example

SOL prototypes 5+ enables users to edit their own comments after submission without restrictions.

Evidence

The recommendations emerged from the scenario-based design process (see 6.5, Scenario 1) and are supported by the literature (see 2.3.3.3 and 2.4.2) and by findings from interviews suggesting that many visitors see control over content unjustly skewed towards the organisation (see 5.3.8). With regard to the implementation example, analytics data from *Home*Sick shows that the comment editing functionality was used (see 8.5.4.3.3), proving demand.

9.6.4 Agency in community

Recommendations

SOLs should provide suitable tools and mechanisms for users to engage with each other and have a say in what kind of content is valued and acceptable. This includes the ability to reply to comments (FL35, FV5, FS20), rate comments (FL28, FL33, FS5) and flag comments for moderation (FL29, FS7, FX3).

Implementation Example

SOL prototypes implement a linear rather than threaded commenting model, where visitors can refer to each other’s username when replying comments, and provide functionality to rate and flag comments for moderation. Comment ratings directly affect their prominence, which is based on a dynamic ranking algorithm that takes into account comments’ rating and recency. The number of up/down votes for each comment are shown on the situated SOL display to make users aware of their agency in the ranking of content. (Flagging for moderation is discussed in 9.7.2).

Evidence

The recommendations emerged from the scenario-based design process (see 6.5, Scenarios 1 and 2) and are supported by literature (see 2.3.3.2, 2.3.3.3 and 2.4.2) and interviews with museum professionals (7.3.1). With regard to the implementation, the rating functionality in the mobile application was little used (see 8.5.4.3.3), however, many visitors touched the thumbs up/down icons on the SOL display (see 8.5.4.3.1), suggesting interest in comment rating.
9.6.5 Interaction feedback

Recommendations
From a usability perspective, control is closely linked to visibility of state, which enables users to understand their interaction and react to problems. SOLs should provide prompt interaction feedback (FL6). Submitted comments should be displayed without delay (FL27, FS12, FS23) and flagged comments should be instantly hidden and replaced with a message explaining that they are under moderation (FS9).

Implementation Example
The evaluated SOL prototypes display comments immediately. A ranking algorithm ensures that newly submitted comments are top-ranked for a short period and therefore instantly visible on the SOL display and in the mobile application. Flagged comments are instantly hidden and replaced with a temporary message explaining that they are under moderation.

Evidence
The recommendations emerged from the scenario-based design process (see 6.5, Scenarios 1 and 2) and are supported by literature (see 2.2.2.3). Observations in user testing sessions show that most users posting a comment via their mobile device look at the SOL display immediately after submission to verify that the comment has arrived (see 8.4.3.3, OT14).

9.7 Content moderation

9.7.1 Separation of monitoring and moderation

Recommendations
In order to not strain museums’ limited resources while also ensuring that submitted comments are promptly displayed (see 9.6.5), SOLs should implement a community moderation model that delegates content monitoring to the community and enables museum staff to act in a timely manner to moderation requests (FX2, FX3, FX4).

Implementation Example
SOL prototypes 5+ display submitted content immediately. They provide functionality for visitors to flag offensive comments for moderation and for museum staff to review moderation requests and then either reset flagged comments or block them permanently.

Evidence
The recommendations are based on literature (see 2.3.3.2), visitor interviews (see 5.3.6) and interviews with museum professionals (see 7.3.1).
9.7.2 Monitoring

Recommendations

In order to support community monitoring, SOLs should provide functionality for users to flag comments for moderation (FL29, FS7, FX3) and optionally attach a message to the moderator to explain their reasons (FS8, FS43). Flagged comments should be hidden immediately and replaced with a notice explaining that they are under moderation (FS9).

Implementation Example

SOL prototypes 5+ provide functionality in the mobile application to flag comments as part of the browsing experience. When flagging a comment, users can optionally enter a message to the moderator explaining their reasons. Flagged comments are hidden immediately from public view on the SOL display, mobile application and RSS feed, and a message is shown instead explaining that they are under moderation.

Evidence

The recommendations emerged from the scenario-based design process (see 6.5, Scenarios 1 and 5) and are supported by literature (see 2.3.3.2) and interviews with museum professionals (see 7.3.1). With regard to the implementation example, analytics data from Home\$ick shows that the flag screen in the mobile application was called up (see 8.5.4.3.3), proving that the functionality is discoverable.

9.7.3 Moderation

Recommendations

The SOL backend should provide moderation tools (FS40) for museum staff to find, read, block and un-block flagged content (FX2) without the need to be present at the related object (FX1). As moderation requests need to be dealt with quickly and museum staff cannot be expected to be at their desk all the time, notifications should be sent to moderators' desktop and mobile devices (FS42, FX4). Moderation requests should contain enough information to make a decision on the spot (FS43), offer mechanisms to instantly reset or block flagged comments (FS44) and provide interaction feedback indicating whether a comment was successfully reset or blocked (FS45).

Implementation Example

The SOL prototype 7 backend keeps a list of moderator email addresses for each museum and provides a web-based administration panel to browse, read and moderate comments. When a comment is flagged for moderation, the backend registers the request and sends an email notification to the desktop and mobile devices of all designated moderators. The email contains the flagged comment, an optional visitor message explaining why the comment was flagged and two hyperlinks that enable moderators to instantly reset or
block the flagged comment. In both cases a confirmation message is generated to indicate the success (or failure) of the operation.

Evidence

The recommendations emerged from the scenario-based design process (see 6.5, Scenario 5) and are supported by findings from expert interviews (see 7.3.1).

9.8 Information design

9.8.1 Glanceability

Recommendations

SOLs should cater for users at different stages of attention and engagement (FL1). They should use clean, uncluttered screen designs (FC4). Key information should be quick and easy to read (FL2, FC2, FC8). Technical aspects of the interaction (e.g. QR codes) should be de-emphasised to not discourage focused attention and engagement.

Implementation Example

SOL prototype 7 uses large fonts and graphical symbols for glanceable information that might be read from distance, such as the number of comments indicating community interest in an exhibit or a generic "touch screen" icon indicating interactivity. While SOL prototype 5 prominently displays a QR code on its default screen (Figure 28), prototype 7 de-emphasises the QR code by integrating it with other connection information and, depending on design variation, showing it only on secondary screens (Figure 55).

Evidence

The recommendations are based on literature (see 2.2.2), co-design sessions with users (see 8.4.4.2 and 8.4.4.6) and empirical evaluations. Observations show that SOL prototype 5, which prominently displays a QR code, receives considerably less attention from visitors (see 8.3.4.1) than prototype 7, which de-emphasises connection information (see 8.5.4.1). Despite the overall high attention rate for prototype 7, many visitors initially had wrong assumptions about the purpose of SOLs when first noticing them (see 8.5.4.4.1). While this reflects unfamiliarity with the concept of SOLs, it also indicates that glanceable information in the current design could be improved.

9.8.2 Learnability

Recommendations

Interaction with SOLs should be easy to understand (FL3) for first-time and repeat users (FL13, FL36). Interactive elements should be clearly labelled (FL12, FT6, FT8, FC3) and designed to avoid ambiguities (FL12, FT9). SOLs should provide visual clues to distinguish between interface and user-generated content (FS15, FT5).
Implementation Example

Most aspects of the user interface in SOL prototype 7, including prompts, icons, URLs and terminology were refined through user-testing and co-design sessions to ensure the interaction is easy to understand. SOL prototype 7 displays meta-data below comments (author's name, date posted, current rating) that helps users to distinguish between interface and user-generated content.

Evidence

The recommendations are supported by literature (see 2.2.2.3 and 2.2.3.3), findings from the user-testing and co-design sessions (see 8.4.3 and 8.4.4) and empirical evaluations. Analytics data suggests that while many users focused on faux affordances (Saffer, 2013) in their interaction with the idle screen, others correctly understood the whole screen to be interactive (see 8.5.4.3.1, Table 37). In the browse and idle screens, most users correctly identified interactive screen elements (see 8.5.4.3.1), supporting results from the co-design sessions (see 8.4.4). 81% of visitors who had been observed to interact with SOLs, all of whom can be assumed to be first-time users, stated in interviews that it was clear how they work (see 8.5.4.4.5), attesting the design of prototype 7 good learnability.

9.8.3 Persuasiveness

Recommendations

SOLs should display suitable information to advertise their interactivity and encourage engagement (FP15) but avoid stating the obvious (FC2). Prompts to action, either as text or in graphical form, are generally more effective in encouraging engagement than efforts to integrate SOLs with the information environment (Brewer, 2004) via an exhibit-specific question or image.

Implementation Example

Some design variations of SOL prototype 7 display prompts to action, either as text or as a "touch screen" icon, while others show instead an exhibit-specific question or icon (replicated on the traditional object label) to encourage engagement by association.

Evidence

The recommendations are based on findings from early prototyping (see 8.2.4), co-design sessions (see 8.4.4.2) and empirical evaluations. Designs with an exhibit-specific icon or question had consistently lower engagement rates than alternative designs showing a generic "touch screen" icon or call to action (see 8.5.4.2.2).
9.8.4 Text information

Recommendations

SOLs should use clear, large fonts that are easy to read (FL2), even by people with weak eyesight (FS19). In order to make information easy to find and read in screens with a high information density, SOLs should optimise their information architecture (FL41, FT4) and use appropriate white space (FL40, FC4).

Implementation Example

SOL prototype 7 uses a custom sans serif font (VAG Rounded\(^{32}\)) that is compact, optimised for reading at various distances and satisfies museums’ aesthetic requirements (FX23). Font sizes range from 64pt\(^{33}\) for glanceable information to 32pt for focused engagement and 18pt for detailed help information. All designs use white space to increase readability.

Evidence

The recommendations are supported by literature (see 2.4.3) and findings from co-design sessions (see 8.4.4.2). Regarding the implementation, user testing with SOL prototype 6 suggests that participants needed little time to read information in the browse screen but longer to read the help screen (8.4.3.2), which consequently has been redesigned in prototype 7 to reduce its information density.

9.8.5 Graphical symbols

Recommendations

SOLs should use graphical symbols that are well understood (FT9). Comprehension of less well-known graphical symbols should be supported with a clear text label (FL12, FT8, FC3).

Implementation Example

SOL prototype 7 uses commonly recognised graphical symbols such as sideways carets to navigate to the previous and next comment in the browse screen and Antenna Design’s MetroCard “touch screen” icon described in Saffer (2013). Custom icons such as the NFC symbol or the "add comment" button have been optimised for recognisability in empirical user studies.

Evidence

The recommendations are supported by literature (Geven et al., 2007) and findings from user testing, co-design sessions and empirical evaluations. The navigation buttons in the browse screen were well recognised by participants in user tests (8.4.3.1). Results from co-
design sessions indicate that most participants preferred designs combining a meaningful graphical element with a clear "Add Comment" text label to avoid uncertainty (see 8.4.4.3). While the generic NFC tag used in Fail Better (see 8.3.3.1) was often misunderstood as a push button and the standard NFC symbol was misinterpreted in user tests (see 8.4.3.3) and on the first day of Home\Sick, the custom NFC symbol used for the remainder of the exhibition was well understood by visitors (see 8.5.4.3.2).

9.9 Conspicuousness

9.9.1 Physical design

Recommendations

SOLs should be presented in a way that is visually pleasing and integrates with the exhibition design (FX23, FP9). They should look polished and professional (FP10) and avoid showing software glitches or errors (FP14). They should not grab visitors’ attention (FX20) or distract form the exhibit (FL44, FX19). The display size should be appropriate for the exhibit (FX22) and large enough to advertise multiple options for mobile access (FX21).

Implementation Example

SOL prototypes 4+ use a 6in (152mm), passive-light, monochrome, e-ink screen with display qualities comparable to print materials. Custom casings made by SGD for Fail Better (Figure 31, p.172) and Home\Sick (Figure 55, p.213) ensured that they integrate well with the exhibition design.

Evidence

The recommendations are supported by literature (see 2.4.4), interviews with museum professionals (see 7.3.6), experiences from early prototyping (see 8.2.3 and 8.2.4) and empirical evaluations. SOL prototype 7 attracted on average similar levels of attention as traditional object labels (see 8.5.4.1.2), suggesting that the monochrome e-ink screen and custom casings strike a good balance between attracting attention and not distracting from the exhibit. However, e-ink screens also have disadvantages as their slow refresh rates and occasional flicker can be unsettling (see 8.4.3.3, OT16), and some users might not realise that they are interactive (see 8.5.4.4.2) and would be more likely to engage with luminous colour screens (see 8.5.4.4.4, Table 38).

9.9.2 Placement

Recommendations

Considering that SOLs should encourage engagement but not distract from the exhibit (FL44, FX19), simple heuristics such as installing SOLs close to eye-height (FL16) in a position with a sustained flow of people and sufficient empty space around them for interaction
(FL17) should be complemented with a more detailed assessment of the attention potential of prospective placements.

**Implementation Example**

The discussion of placement options in *Home\Sick* (see 8.5.2.1) develops the idea of an *attention potential* and presents a related tool, based on aspects identified by Bitgood (2009a, 2009b) to affect the level of attention that exhibits and labels receive, to assess the attention potential of four specific SOL installations.

**Evidence**

The recommendations are supported by literature (see 2.4.4) and findings from empirical evaluations. The research shows that placement is an important factor in how much attention and engagement SOLs receive (see 8.5.4.1.1 and 8.5.4.2.2). While the evaluation at *Home\Sick* was not designed to prove causality between placement-related factors and attention and engagement rates, it has shown that there is a strong and significant correlation between attention potential and actual attention and engagement (see 8.5.5.2).

**9.10 Robustness**

**9.10.1 Physical robustness**

**Recommendations**

SOLs should have casings that prevent users from accessing critical controls on the display unit, such as home or power buttons (FP3) while at the same time allowing admin staff to easily access these critical controls and to swap out the display unit (FP4). Casings should be simple and compact unless there is a clear reason for unconventional designs (FC1). Casings should be robust and support a range of options that allow for easy mounting and unmounting (FL39, FP5) and protect against vandalism and theft.

**Implementation Example**

Casings developed for SOL prototypes 2+ shield hardware buttons and power connectors from visitors while prototype v3+ gives administrators full access to the display unit, allowing it to be swapped out after installation. They are sturdy in construction and offer simple mounting options that hide fixings to prevent theft.

**Evidence**

The recommendations are supported by literature (Ballagas et al., 2004) and findings from early prototyping (see 8.2.2), co-design sessions (see 8.4.4.1) and two field trials where battery-operated displays needed to be regularly swapped out after installation (see 8.3.2.3 and 8.5.2.3). There were no cases of vandalism or theft in either field trial, however, this might in part be due to the low-risk environment and the presence of student mediators in the gallery space at SGD at all times (see 8.3.2.5 and 8.5.2.2).
9.10.2 Technical robustness

Recommendations

SOLs should support a range of communication models and technologies (FL20, FP1, FP11), be tolerant to unreliable network connections (FL51) and automatically try to reconnect when a network connection is dropped (FP13). They should support both mains and battery powered operation (FS30, FX26).

Implementation Example

The evaluated SOL prototypes support mains- and battery-powered operation with automatic fall-back to battery. They support a range of communication models (Appendix C) and technologies, including WiFi and mobile networks. In order to cope with weak and unreliable wireless network signals, SOL prototype 7 automatically attempts to re-connect when a connection is dropped until connectivity is restored.

Evidence

The recommendations emerged from the scenario-based design process (see 6.5, Scenario 4) and are supported by literature (see 2.2.4 and 2.4.5), interviews with museum professionals (see 7.3.6) and experiences from early prototyping (see 8.2). Both field trials relied on SOLs being able to run on battery when attached to exhibits where no mains power was available (see 8.3.2.3 and 8.5.2.3) and used an open communications model where visitors can connect either via the museum’s free wireless network or via their mobile network. While there were some networking problems during Fail Better with SOL prototype 5 (see 8.3.2.3), no such problems were experienced during Home\Sick with prototype 7 (see 8.5.2.3), which automatically reconnects when a network connection is dropped.

9.10.3 Interaction robustness

Recommendations

SOLs supporting direct interaction should time-out and automatically return to the idle screen after a certain period of inactivity (FT1). Administration functionality should be password protected and implemented in a way that minimises the chance of accidental activation by visitors (FS36).

Implementation Example

SOL prototype 7 automatically times out after 180 sec of inactivity on the browse or help screens and returns to the idle screen, which is optimised to encourage engagement. The administration mode is accessed by touching the very top right corner of the screen, which shows a password dialogue that either activates the administration mode or disappears if the wrong password is entered. The password dialogue itself times out after 15 seconds of inactivity to reset the user interface after accidental activation.
Evidence

User tests with prototype 6, which had a "close" button in the help and the browse screens, show that less than half of all participants closed the help screen after reading it and not a single participant closed the browse screen when finished reading comments (see 8.4.3.1). The need for timeouts is further confirmed by analytics data from Home\Sick, which involved prototype 7 and recorded a high number of help screen timeouts despite the help screen having an "OK, got it" button for visitors to close it (see 8.5.4.3.1). The analytics data showed no incidents of accidental admin panel activation (e.g. wrong admin password or timed out dialogue).

9.10.4 Maintenance support

Recommendations

SOLs should display status notifications when running low on battery or losing network connection (FS29) to support maintenance by staff present in the gallery. They should keep technical logs for debugging and post-hoc analysis of problems (FP2) and report status information to the backend (FS32, FS33). The backend should provide suitable tools for non-technical staff to remotely monitor SOLs installed in an exhibition (FL21, FS35, FS39) and provide access to visitor comments and moderation tools (FS40, FS44, FX1, FX15, FX16). In addition, SOLs should support remote software installation to facilitate rollouts of new software versions (FL22).

Implementation Example

SOL prototypes 5+ display notification icons in the top left corner of the screen when loosing network connection or running low on battery. All SOL prototypes keep technical logs for debugging and problem analysis. Prototype 7 reports status information back to the server and provides a Web-based, password-protected admin panel (Figure 59, p. 217) where museum staff can login to monitor the battery level and connection status of installed SOLs and access submitted comments and moderation tools. The backend notifies administrators by email of critical SOL states and new moderation requests to improve responsiveness. SOL prototype 7 supports remote software updates, which are downloaded and installed automatically from the backend. To support this process, the backend reports the latest software version code when SOLs connect to it in configuration mode, and makes the corresponding application installer available online.

Evidence

The recommendations emerged from the scenario-based design process (see 6.5, Scenario 4) and are supported by literature (see 2.2.4) and by interviews with museum professionals (see 7.3.1 and 7.3.5). With regard to the implementation example, the admin panel was welcomed by museum staff, however, there is no data available on actual use or user experience. The software update mechanism was used during Home\Sick (see 8.5) to push out a minor software update improving the collection of interaction log data.
10 Conclusions

Taking a problematic user experience with ubiquitous annotation as its point of departure, this thesis defines and explores the design space for SOLs, small interactive displays aiming to support users' in-situ engagement with digital annotations of physical objects and places by providing up-to-date information before, during and after interaction.

While the concept of ubiquitous annotation has potential applications in a wide range of domains, the research focuses in particular on SOLs in a museum context, where they can support the organisation’s educational goals (Falk and Dierking, 2000) by engaging visitors in the interpretation of exhibits and help towards the "democratisation of heritage" (Taylor and Gibson, 2016) by providing an outlet for otherwise ephemeral popular reactions and opinions that can complement official interpretations by the institution.

Reflecting this focus, the thesis defines and structures the design space for SOLs (RA1), investigates museum visitors’ mental models of commenting (RA2) and develops design recommendations for SOLs in museums (RA3). Table 41 lists specific objectives set out in the introduction (see 1.3) and how they are met by the research.

<table>
<thead>
<tr>
<th>Research objective</th>
<th>Related aims</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>RO1. Carry out a literature review to contextualise the research</td>
<td>RA1, RA2, RA3</td>
<td>Chapter 2</td>
</tr>
<tr>
<td>RO2. Analyse and synthesise design guidelines and taxonomies for related display concepts</td>
<td>RA1</td>
<td>Chapter 4</td>
</tr>
<tr>
<td>RO3. Distinguish SOLs from related display concepts and identify design aspects not covered in existing taxonomies and heuristics</td>
<td>RA1</td>
<td>Chapter 4</td>
</tr>
<tr>
<td>RO4. Carry out a survey to investigate visitors’ mental models of commenting in museums and translate findings into requirements</td>
<td>RA2, RA3</td>
<td>Chapter 5</td>
</tr>
<tr>
<td>RO5. Carry out design activities to analyse the requirements and preferences of museum professionals and potential users</td>
<td>RA1, RA3</td>
<td>Chapters 6, 7, 8</td>
</tr>
<tr>
<td>RO6. Iteratively develop SOL prototypes fit for deployment in museums.</td>
<td>RA1, RA3</td>
<td>Chapter 8, Appendix B</td>
</tr>
<tr>
<td>RO7. Empirically evaluate SOL prototypes in a real museum context</td>
<td>RA2, RA3</td>
<td>Chapters 8.3, 8.5</td>
</tr>
<tr>
<td>RO8. Synthesise findings from all research activities to formulate design recommendations for SOLs in museums</td>
<td>RA3</td>
<td>Chapter 9</td>
</tr>
</tbody>
</table>

*Table 41: Mapping research objectives to research aims and thesis chapters*

The following sections discuss how the thesis answers the research questions set out in the introduction, restate its contribution from ubicomp, application, domain and methodology perspectives and outline future research directions.
10.1 Summary of findings

This section revisits the research questions formulated in the introduction of this thesis (see 1.4) and discusses related findings.

RQ1. How to define and structure the design space for SOLs?

- How do SOLs relate to similar display concepts and what distinguishes them?

Sections 2.2.1, 4.2 and 4.3 look at taxonomies and heuristics to examine how SOLs relate to, and can be distinguished from, similar display concepts described in the literature. While SOLs share many design aspects with the wider families of ambient displays and interactive public displays, their particular purpose of supporting in-situ social object annotation manifests itself in a set of characteristics that cannot be found in that combination in other display concepts (see 4.2).

- What are the salient design aspects of SOLs?

Section 4.7 describes ten high-level design aspects for SOLs based on a systematic process of analysing existing taxonomies and heuristics for similar display concepts, synthesising relevant design aspects, complementing them with salient aspects emerging from the iterative design process and finally pruning and synthesising the results (see 4.3 to 4.6). In addition to structuring the design space, the final sections in Chapter 4 also discuss tensions between the identified design aspects and assess their validity and transferability to other display concepts.

RQ2. How can SOLs support commenting in museums?

- What are visitors' preferences and expectations for commenting?

Chapter 5 reports on a visitor survey involving 104 structured interviews carried out at three different museums ranging from a small urban art gallery with a local audience to a large metropolitan museum with an international audience. The survey provides insights into visitors' preferences, expectations and mental models of commenting in museums. In particular, it investigates their preferences for commenting mechanisms, interest in comment metadata, expectations of readership, assumptions about comment moderation and conservation, and views on IP ownership and reuse of comments. A summary of findings is provided in section 5.4 and limitations of the study are discussed in section 5.5.

- How do these translate into requirements for SOLs?

Requirements for SOLs emerging from the visitor survey are identified throughout the discussion of findings (see 5.3). Specific requirements are marked in the main text to allow readers to contextualise and scrutinise them. A list of all requirements from the visitor survey and other research activities is provided in Appendix A.
RQ3. How should SOLs be designed and integrated with museum environments?

- How to attract attention and encourage engagement?

Section 4.8 discusses a fundamental design tension for SOLs in museums contexts between attracting attention and not distracting from the related exhibit. Bearing this in mind, the thesis offers a range of design recommendations on how to predict (see 8.5.5.2), assess (see 9.3) and adjust (see 9.2, 9.8, 9.9) the levels of attention and engagement SOLs receive and how to encourage and support interaction (see 9.4, 9.5, 9.6, 9.8). The recommendations are informed by findings emerging throughout the research, including two field trials of SOL prototypes assessing attention and engagement rates in gallery environments and exploring visitors’ mental models and barriers to engagement (see 8.3 and 8.5).

- How to support mobile interaction with SOLs?

The thesis provides design recommendations on how to support mobile interaction with SOLs through technical means (see 9.5.1), interaction feedback (see 9.6.5), suitable information design (see 9.4.3 and 9.8) and ergonomic placement (see 9.4.5). The recommendations are informed by findings emerging throughout the research, including early prototyping (see 8.2), formative user-testing and co-design sessions (see 8.4) and two field trials of SOL prototypes in gallery environments (see 8.3 and 8.5).

- How to balance interaction between mobile and SOL?

Sections 9.5.1 and 9.5.2 offer recommendations on how to distribute interaction between mobile device and SOL. They are informed by formative user-testing and co-design sessions (see 8.4) as well as two field trials balancing interaction in different ways, including one where SOLs are used purely for information display and all interaction takes place on the mobile device (see 8.3), and another where SOLs support content browsing on the situated display and the mobile device, but require mobile interaction to contribute content (see 8.5).

- How to integrate SOLs with the physical, technical and information environment?

Reflecting the particular design perspective of SOLs as a generic platform rather than a bespoke system developed for one particular context, recommendations in section 9.2 discuss integration with the environment mainly in the context of plasticity, i.e. the capability to dynamically scale, customise and configure SOLs for different environments. Other design recommendations in this context relate to interrogability (see 9.3), information design (see 9.8) and robustness (see 9.10). The recommendations are informed by findings emerging throughout the research and in particular by experiences from the early prototype development (see 8.2) and two field trials in gallery environments (see 8.3 and 8.5).
10.2 Learning about the process

A key characteristic of the adopted design research approach is to evaluate prototypes in realistic settings to increase the ecological validity of findings. This applies in particular to the design recommendations under RQ3 and the experientially informed design aspects of the SOL design space under RQ1, which both draw on findings from informal evaluations, user-testing and co-design sessions carried out in public settings (see 8.2 and 8.4) and from two field trials in live gallery settings (see 8.3 and 8.5). In this context, the thesis offers some insights on how geographical distance, lack of control and insufficient communication with museum partners can impact on research studies (see 8.2.5, 8.3.6, 8.4.6, 8.5.6) and how curatorial practices and constraints take precedence over research aspects when evaluating designs in live gallery environments (see 8.5.6). While these experiences are specific to this thesis research, it is hoped that they can inform other research efforts evaluating interactive technologies in museums.

10.3 Restatement of contributions

Analogous to the four perspectives offered in the literature review contextualising the research, this section structures contributions of this thesis into ubicomp, application, domain and methodology perspectives.

Ubicomp perspective

From a ubicomp perspective, the main contribution of this thesis is to define and structure a design space for SOLs as a display concept with its own particular set of characteristics. While there is a large body of literature on public, pervasive and ambient displays, including for place-based messaging and community engagement, the concept of peripheral displays for social object annotation analogous to social annotation on the Web has not yet been defined or systematically described. The delineation and structuring of the design space helps to clarify terminology and support its further exploration in future research efforts.

Unlike a display taxonomy, which typically offers dimensions and metrics to categorise displays in a positivist paradigm, the design space structure reflects the developmental character of design research methodology and identifies salient aspects in the sense of problem areas that need to be addressed when developing SOLs. Given the overlap with related display concepts, many aspects of the developed design space structure also apply to other displays that are public, interactive and/or driven by user-generated content. Two design aspects in particular, plasticity and interrogability, apply to any generic ubicomp system that needs to be customised and researched in different target environments.

Application perspective

From an applications perspective, the main contribution of this thesis are design recommendations for SOLs, together with implementation examples and supporting evidence from research activities. The recommendations enrich and concretise the
developed design space structure with a particular focus on in-situ content creation and consumption to support visitors' social interpretation of exhibits in museums. In addition to informing future research in this particular application context, the recommendations are also relevant for other applications and display concepts sharing characteristics of in-situ social content creation and related design problems with SOLs.

**Domain perspective**

From a domain perspective, the main contribution of this thesis are first insights into visitors' expectations, preferences and mental models of commenting in museums. While the literature discusses visitor comments from a museum perspective, with regard to engagement, interaction, learning, moderation and content quality, little is known about visitors' views on commenting in museums. The survey presented in Chapter 5 addresses this gap with findings on a wide range of aspects ranging from preferences for commenting mechanisms to views about ownership and potential reuse of comments.

On a practical level, another contribution of the research is the design and implementation of a generic commenting platform for museums, including backend, mobile application and SOLs, which is fully functional and ready for ad-hoc deployment at minimal costs. Given that the majority of cultural heritage organisations are small scale and have limited budgets that do not support custom IT development, the developed system has the potential to directly benefit smaller museums and their audiences by offering an affordable and readily available platform for social interpretation.

**Methodology perspective**

From a methodology perspective, this thesis makes several smaller contributions, each of which holding promise to enrich the methodology toolset in pervasive display research but requiring further development and validation to assess their substance and usefulness.

Branching scenarios (see 6.5) extend scenario-based design practice by abandoning linear single-narrative scenarios in favour of a branching structure that accounts for multiple possible user behaviours in a given situation and reflects evolving designs and capabilities of the developed system, making them more suitable for an iterative design process.

The developed instrument to assess and quantify the attention potential of display placements (see 8.5.2.1 and 8.5.5.2) goes beyond simple placement heuristics discussed in the literature and shows promise in predicting attention and engagement rates to scope expectations and inform mitigating measures in actual deployments.

Finally, the open-source implementation of a real-time data analytics and visualisation tool (see 8.5.3.3) can support the research and iterative design of pervasive display applications and answers calls in the literature for methods and tools to evaluate ubicomp technologies in authentic settings.
10.4 Open issues and future work

Keeping with the previous section, the discussion of open issues and future work is structured into the four perspectives ubicomp, application, domain and methodology.

Ubicomp perspective

The research shows that technological aspects are still a barrier to mobile engagement with SOLs. Apart from connectivity issues, this relates in particular to real and/or perceived difficulties in connecting a mobile device. Key problems in this context are the lack of commonly supported technologies and related conceptual models for PMI. Both of these, however, are likely to be resolved over time. PMI technologies are fast evolving, with new developments ranging from mainstream approaches such as iBeacon34 and Eddystone35 to more experimental technologies such as data transfer via ultrasound36 or Acoustic Barcodes (Harrison, Xiao and Hudson, 2012). At the same time contactless mobile payment, the first mainstream application involving PMI, is gaining momentum (Deloitte, 2016) and might help to popularise the interaction pattern and lower the threshold for mobile engagement with other services. Together, these developments promise to simplify interaction with SOLs in the future and allow for simpler, smaller designs as there is no need to support multiple technologies and display related connection information for each of them. Future research should revise the developed design recommendations for SOLs once PMI patterns are better established and have converged around a common set of technologies.

Beyond mobile interaction, visitor interviews in museums have shown that many people value the haptic qualities typically associated with physical interaction such as leafing through a visitor book or writing with a pen on paper. While current technologies are not able to satisfactorily reproduce these qualities (Cho et al. 2016), research efforts are underway to close this gap (ibid). Future research should revisit this aspect and explore direct interaction designs taking advantage of these developments.

From an administrative perspective, many design features of the developed SOL prototypes are at least in part motivated by maintenance concerns, such as extending battery life, monitoring energy levels and being able to swap out displays low on battery. In the light of recent research into powering e-ink displays via NFC energy harvesting (Dementyev et al., 2013), which demonstrates the feasibility of self-sustained interactive displays with no need for batteries or external power, future research should explore the possibility of more lightweight and maintenance-free SOL designs and review related recommendations.

Application perspective

While ubiquitous annotation can involve a wide range of content types, the research so far has focused in particular on text comments. With regard to the low contribution rates

34 iBeacon homepage: https://developer.apple.com/ibeacon/
35 Eddystone homepage: https://developers.google.com/beacons/
36 Chirp homepage: http://www.chirp.io/
observed in the field trials, future research should explore different content types that might tap into different motivations and interests and thereby increase active participation. This could include support for different media such as audio or video as well as options to simply rate objects, the latter implemented in SOL prototypes 5+ but not evaluated so far. Beyond social interpretation in museums, there are many other application domains where SOLs could be useful including, for instance, tourism, remembrance, civic engagement and retail. Future research should build on the generic character of SOLs and branch out into these domains with a view to testing the concept in different application contexts and adapting and complementing the developed design recommendations accordingly.

**Museum perspective**

Some design aspects of SOLs have not been sufficiently clarified by the research. This includes in particular the effectiveness of questions as a means to increase engagement and raise the quality of contributions, and the effectiveness of comment ratings to give users agency in promoting quality content. Both of these aspects require more work to fully investigate. Another line of enquiry to follow up concerns the use of more conspicuous SOL designs involving luminous colour displays to raise attention rates. While the evaluated e-ink display designs strike a good balance between attracting attention and not distracting from exhibits, the research indicates that some visitors would prefer more colourful designs and that more luminous display designs would widen deployment options.

A key value proposition of SOLs is that they collect otherwise ephemeral visitor comments, which inherently become more valuable and interesting as an interpretive resource as they accumulate over time and become part of an object's historic record that documents how perceptions change and evolve. Future research should evaluate SOLs in longitudinal studies with permanent rather than temporary exhibitions, where visitor comments can accumulate over several years.

Finally, considering Bradburne’s (2002) account of different traditions of interactivity in art and science museums, future work should evaluate SOLs in different types of museums. Of particular interest in this context would be modern art museums, which typically place less emphasis on interaction but foster a more contemplative atmosphere and display divisive objects that provoke strong opinions in visitors.

**Methodology perspective**

This thesis makes several tentative methodological contributions, including branching scenarios supporting scenario-based design, an instrument to assess and quantify the attention potential of display placements and a data analytics and visualisation tool to investigate interaction with situated displays. Future research should further develop and validate each of these tentative contributions with a view to enriching the methodology toolset in pervasive display research.
10.5 Closing remarks

This thesis introduces SOLs as a display concept with its own particular problem space and design characteristics. It presents findings from a first exploration of their design space in a museum context, however, given the wide range of possible application domains and the rapid development of relevant technologies, it is clear that the research only represents a small step towards a comprehensive understanding of SOLs and only a snapshot based on current technologies and interaction patterns.

We believe that SOLs have the potential to become ubiquitous in our environment just as commenting, ratings and user-generated content in general have become ubiquitous on the World Wide Web. Hopefully the work presented in this thesis is of use to researchers and practitioners seeking to improve the user experience of ubiquitous annotation and helping people to express their views with effectiveness, efficiency and satisfaction.\(^37\)

\(^{37}\) The three constituent aspects in the ISO 9241-11 definition of usability.
Related publications

Winter, M., Pemberton, L. and Griffiths, R. (2016). Direct and Mediated Interaction with Social Object Annotations in Museums. Accepted for Digital Research in the Humanities and Arts Conference (DRHA 2016), 4-7 Sep 2016, Brighton, UK.


References


References


References


- 300 -


References


References


References


References


- 313 -


### Appendix A: Complete list of formative findings

Formative findings identified throughout the research, including requirements, design guidelines and user preferences together with relevant page numbers where they are discussed in context. Note the list does not include findings from the two empirical evaluation studies, which are discussed in detail in Chapters 8.3 and 8.5.

<table>
<thead>
<tr>
<th>Findings from the literature review (Chapter 2)</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>FL1: The display should address all levels of attention and stages of engagement</td>
<td>21</td>
</tr>
<tr>
<td>FL2: Key information on the display should be quick and easy to read</td>
<td>22</td>
</tr>
<tr>
<td>FL3: Interaction with the display should be easy to understand</td>
<td>22</td>
</tr>
<tr>
<td>FL4: The system should streamline engagement and avoid interruptions</td>
<td>22</td>
</tr>
<tr>
<td>FL5: The display should support multi-user interaction</td>
<td>22</td>
</tr>
<tr>
<td>FL6: The display should provide prompt interaction feedback</td>
<td>22</td>
</tr>
<tr>
<td>FL7: Interaction should avoid or minimise social embarrassment</td>
<td>23</td>
</tr>
<tr>
<td>FL8: IDs should be unique, inexhaustible in supply and easy to produce</td>
<td>25</td>
</tr>
<tr>
<td>FL9: SOLs should provide alternative encodings of identifiers, including a human-readable encoding that enables users to react to errors</td>
<td>25</td>
</tr>
<tr>
<td>FL10: Tags should support quick and reliable reading and tag readers should be of a reasonable size and cost</td>
<td>26</td>
</tr>
<tr>
<td>FL11: The display should support multiple alternative interaction models to cater for different contexts and user preferences</td>
<td>27</td>
</tr>
<tr>
<td>FL12: Interactive elements should be clearly labelled and designed to avoid ambiguities</td>
<td>28</td>
</tr>
<tr>
<td>FL13: SOLs should support both first-time and repeat users</td>
<td>29</td>
</tr>
<tr>
<td>FL14: SOLs should be placed in a way that avoids social embarrassment and unnecessary exposure of users</td>
<td>30</td>
</tr>
<tr>
<td>FL15: The purpose and interaction should be clearly explained to support users forming mental models of SOLs</td>
<td>30</td>
</tr>
<tr>
<td>FL16: SOLs should be placed at eye-height or close to eye-catching objects to increase awareness</td>
<td>31</td>
</tr>
<tr>
<td>FL17: SOLs should be placed at a suitable height for comfortable interaction</td>
<td>32</td>
</tr>
<tr>
<td>FL18: SOLs and their positioning must comply with public law, including accessibility legislation and health and safety regulations, as well as organisational rules and regulations</td>
<td>32</td>
</tr>
<tr>
<td>FL19: SOLs should be placed in a position with a sustained flow of people and sufficient empty space around them for interaction</td>
<td>32</td>
</tr>
<tr>
<td>FL20: SOLs should support a range of networking and power options</td>
<td>32</td>
</tr>
</tbody>
</table>
FL21: The SOL backend should provide functionality to remotely monitor and manage deployed displays ................................................................. 33
FL22: SOLs should support remote software updates ............................................. 33
FL23: SOLs should be able to associate content with specific users ......................... 38
FL24: SOLs should not require users to identify themselves ...................................... 38
FL25: SOLs should give administrators control over the terminology and design of the user interface .................................................................................. 39
FL26: SOLs should provide functionality to moderate user-generated content .......... 39
FL27: SOLs should instantly display submitted content ........................................... 40
FL28: SOLs should enable users to rate comments ................................................... 40
FL29: SOLs should enable users to flag comments for moderation ......................... 40
FL30: SOLs should record engagement statistics for objects and comments, including peripheral aspects such as comment reads and ratings ............................. 41
FL31: SOLs should support alternative contribution modes such as ratings that do not require actual content creation ................................................. 41
FL32: SOLs should record engagement statistics for individual users ......................... 41
FL33: SOLs should provide mechanisms to rate or promote contributions ................ 41
FL34: SOLs should support exhibit-specific prompts or questions ......................... 47
FL35: SOLs should enable visitors to engage with others' comments, e.g. by replying to or rating comments ............................................................... 47
FL36: SOLs should be easy to use and understand for first-time users ....................... 48
FL37: SOLs should give visitors control over their submitted content ....................... 48
FL38: SOLs should come in a range of different sizes .............................................. 48
FL39: SOLs should support a range of mounting options ........................................ 48
FL40: SOLs should use clear, large fonts and appropriate white space to make them easy to read ........................................................................... 50
FL41: SOLs should have a highly optimised information architecture to make information easy to find and read ................................................................. 50
FL42: SOLs should provide functionality for administrators to monitor and analyse user engagement and interaction .............................................. 50
FL43: SOLs should provide functionality to dynamically change screen designs and user prompts even after deployment .................................................. 50
FL44: SOLs should not distract visitors or divert their attention from exhibits .......... 51
FL45: Submitted content should be archived and become part of an object's profile ...... 52
FL46: Submitted content should be stored in a future-proof data format ................... 52
FL47: Content submitted to SOLs should be accessible from outside the museum ....... 53
FL48: SOLs should prioritise comments according to their community rating ............ 54
Appendix A: Complete list of formative findings

FL49: SOLs should not require users to install a custom application ................................. 55
FL50: SOLs should not require users to login to read or contribute content ..................... 55
FL51: SOLs should be tolerant of unreliable network connections ................................ 55
FL52: SOLs should be framed in a comprehensive organisational effort to promote mobile technologies and a social visitor experience ................................................. 55
FL53: Content moderation on SOLs should not delay the display of newly submitted comments ......................................................................................................................... 56
FL54: SOLs should collect detailed analytics data about users' interaction and make it available in real-time .................................................................................................................. 60
FL55: SOLs should be able to dynamically change information presentation parameters to support their evaluation in the field ......................................................... 60

Findings from the museum visitor survey (Chapter 5)  Page

FV1: The interaction with SOLs should be as easy and direct as possible, removing any barriers that delay users or require additional cognitive resources when submitting a comment .................................................................................................................. 108
FV2: SOLs should support both in-situ commenting while at the exhibit and remote commenting after the encounter when users had time to reflect .......................................................... 108
FV3: SOLs should give users as much freedom as possible when submitting comments, e.g. not prescribe a specific topic or format and not force them to enter extra information ........................................................................................................ 108
FV4: SOLs should provide information on how the organisation deals with submitted comments ....................................................................................................................................... 108
FV5: SOLs should enable visitors to read and reply to each other's comments .......... 108
FV6: SOLs should enable visitors to share comments with a wider audience outside the gallery ....................................................................................................................................... 109
FV7: SOLs should integrate with personal communication habits and platforms .... 109
FV8: SOLs should protect users' privacy and not force them to identify themselves or automatically link to their online profile .................................................................................................. 109
FV9: SOLs should provide information about who is going to read submitted comments ................................................................................................................................. 112
FV10: SOLs should provide functionality for museum staff to post and reply to comments without being present at the exhibit .................................................................................. 112
FV11: SOLs should mark staff comments so that they are easy to identify by visitors. ... 112
FV12: SOLs should provide functionality for content moderation .................................. 113
FV13: SOLs should separate content monitoring from content moderation ................ 114
Appendix A: Complete list of formative findings

FV14: SOLs should inform users about the institution’s policies with regard to the remediation, harvesting and conservation of comments. .............................. 116
FV15: Visitors should be notified how comments might be used by the museum. ........ 118
FV16: SOLs should provide terms of use in an unobtrusive way. ........................................ 118
FV17: It should be clear to visitors who owns the intellectual property rights to comments submitted to SOLs. ................................................................. 120
FV18: SOLs should provide functionality enabling users to take control of their submitted comments. ................................................................. 120

Findings from scenario modelling (Chapter 6)                                           Page

<p>| | | | | | |</p>
<table>
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<tbody>
<tr>
<td>FS1: SOLs should display information on how to connect a mobile device.</td>
<td>140</td>
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</tr>
<tr>
<td>FS2: SOLs should support multiple methods and technologies to connect a mobile device.</td>
<td>140</td>
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</tr>
<tr>
<td>FS3: The mobile app should display an image or other visual clue that confirms to visitors that they are connected to the right SOL and exhibit</td>
<td>140</td>
<td></td>
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</tr>
<tr>
<td>FS4: SOLs should enable visitors to read comments on their mobile device and on the situated display.</td>
<td>140</td>
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</tr>
<tr>
<td>FS5: SOLs should enable visitors to rate existing comments.</td>
<td>140</td>
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<tr>
<td>FS6: The order in which comments are shown should reflect their recency and community rating.</td>
<td>140</td>
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<td></td>
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<tr>
<td>FS7: SOLs should enable visitors to flag comments for moderation.</td>
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<tr>
<td>FS8: When visitors flag comments, SOLs should enable them to add a message to the moderator explaining the reasons why it was flagged.</td>
<td>140</td>
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<tr>
<td>FS9: SOLs should immediately hide flagged comments and instead display a message explaining that they are under moderation.</td>
<td>140</td>
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</tr>
<tr>
<td>FS10: SOLs should enable visitors to post comments in-situ.</td>
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<tr>
<td>FS11: SOLs should provide an option for visitors to provide a name with their comment. The optional name field should be automatically populated for repeat users.</td>
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<tr>
<td>FS12: SOLs should instantly update after a comment is submitted to give visitors feedback on their interaction.</td>
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<tr>
<td>FS13: SOLs should be able to remember users and their comments without requiring them to register and login.</td>
<td>141</td>
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<tr>
<td>FS14: SOLs should enable visitors to edit their comments after submission.</td>
<td>141</td>
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<tr>
<td>FS15: SOLs should clearly mark visitor comments as content submitted by users and not provided by the gallery.</td>
<td>142</td>
<td></td>
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</tbody>
</table>
Appendix A: Complete list of formative findings

FS16: SOLs should support multi-user scenarios, e.g. enable a user to connect their mobile device while another visitor interacts with the in-situ display and enable multiple mobile devices to be connected at the same time. ........................................ 142

FS17: SOLs should be able to operate on both WiFi and mobile data networks to minimise friction for visitors with or without a data plan when connecting their device. .............................................................. 142

FS18: SOLs should enable users to refer to another comment, e.g. by providing unique comment markers (e.g. user name and date) an author can reference. ... 142

FS19: SOLs should display content in a large enough font size for people with weak eyesight on both the SOL display and the mobile application. ....................... 143

FS20: SOLs should enable visitors to reply to comments. ........................................ 143

FS21: SOLs should provide a help screen explaining that, and how, comments can be added with a mobile device. ................................................................. 143

FS22: The SOL help screen should explain in detail the different ways to connect a mobile device. ........................................................................................................ 143

FS23: Comments should be presented in reverse chronological order. .................. 143

FS24: SOLs should clearly mark comments by museum staff so that visitors can distinguish between the visitor voice and the museum voice. ....................... 143

FS25: SOLs should be customisable with different casings that integrate with the overall exhibition design. ................................................................. 144

FS26: The SOL backend should provide an admin dashboard for "minting" IDs (Kindberg, 2002) and creating digital resources for exhibits. ......................... 144

FS27: SOLs should provide functionality for dynamic registration to exhibits. .......... 144

FS28: SOLs should have a dedicated configuration mode. .................................... 144

FS29: SOLs should indicate their status, including their battery level, connection status and WiFi signal strength. ......................................................... 144

FS30: SOLs should support battery and mains powered operation. ....................... 144

FS31: SOLs should support different layouts and dynamic layout switches. ........... 145

FS32: SOLs should periodically report their battery status to the backend. ............ 145

FS33: SOLs should periodically ping the server to enable detection of loss of connectivity. ................................................................. 145

FS34: The SOL backend should notify administrators via suitable channels when the battery runs low or when the SOL loses network connection. .......... 145

FS35: The SOL admin dashboard should provide status information about SOLs, including battery level, connection status, number of comments and interaction statistics. ......................................................... 145

FS36: SOLs should provide a password-protected way to activate the configuration mode. ........................................................................................................ 145
Appendix A: Complete list of formative findings

FS37: The SOL configuration mode should support functionality to manage network connections. ................................................................. 145
FS38: The SOL admin dashboard should support user management and logins to give administrators access to their organisations SOLs. .................................................. 146
FS39: The SOL admin panel should provide an overview of all SOLs installed in an exhibition. .................................................................................. 146
FS40: The SOL admin panel should provide access to visitor comments and moderation tools........................................................................ 146
FS41: The SOL backend should provide RSS feeds of comments per exhibit. ............................................................... 146
FS42: The SOL backend should notify administrators in real-time via email or other suitable channels when a comment is flagged by visitors for moderation. ................................................................. 146
FS43: Moderation requests should contain enough information for moderators to make a decision on the spot. .............................................................. 146
FS44: Moderation requests should provide suitable back-channels to instantly block or unblock visitor comments. .......................................................... 146
FS45: The SOL backend should provide feedback to moderators indicating whether a comment was successfully blocked or unblocked. .................................................. 146

Findings from expert interviews with museum professionals (Chapter 7) Page

FX1: The system should enable moderators to browse user-generated content without the need to be present at the related object .............................................. 150
FX2: The system should enable moderators to react to moderation requests, i.e. to find, read, block and un-block flagged content .................................................. 150
FX3: The system should enable users to flag content for moderation .......................................................... 150
FX4: The system should notify moderators when content is flagged by users. Notifications should be sent to moderators' desktop and mobile devices 150
FX5: The system should not require users to provide additional information about them when submitting comments .................................................. 151
FX6: Entering meta-data should not be a barrier to contribute content .................................................. 151
FX7: The system should not force users to register and login .................................................................................. 151
FX8: The system should not rely on third-party logins .................................................................................. 151
FX9: Social media integration could be beneficial but is not essential .................................................................................. 153
FX10: Social media integration should not complicate the interaction .................................................. 153
FX11: Remote commenting is not a core requirement for an in-gallery commenting system .................................................. 153

- 320 -
FX12: The system should store comments and interaction statistics in an open format to support data analysis and unspecified future uses .............................................................. 154
FX13: Users should be informed about how their comments might be used, in particular with respect to access, archiving and commercialisation .............................................. 154
FX14: Terms of content ownership and reuse should be displayed in an unobtrusive way that does not create a barrier to participation .......................................................... 154
FX15: The system should provide an easy-to-use dashboard suitable for content moderation by non-technical staff .............................................................. 154
FX16: The dashboard should offer functionality to browse, read, hide, delete and reset comments flagged by users .................................................................................. 154
FX17: The system should make content available in an open, easy and commonly used format such as RSS or JSON .............................................................. 155
FX18: The system should support content syndication with different scopes, including an exhibition and object scope .............................................................................. 155
FX19: Displays should be unobtrusive and not distract from the exhibit .............................................................................................................................. 155
FX20: Displays should use e-ink screens .............................................................................................................................. 155
FX21: Displays should be large enough to show multiple connection options for mobile access .................................................................................................................. 155
FX22: Display sizes should be appropriate for exhibits, e.g. smaller versions should be available for small exhibits .................................................................................. 155
FX23: Displays should be presented in a way that is visually pleasing and integrates with the exhibition design ...................................................................................... 156
FX24: Displays should be mounted appropriately for ergonomic use by people of different heights .................................................................................................................. 156
FX25: Displays should be offered with or without casings depending on the preferences of the host organisation ...................................................................................... 156
FX26: Displays should support mains- and battery-powered operation .............................................................................................................................. 156

Findings from early prototyping (Chapter 8.2)  Page

FP1: SOLs should support multiple networking models to adjust to different contexts and requirements .................................................................................................................. 160
FP2: SOLs should maintain, and make available, technical logs to support debugging and post-hoc analysis of problems .................................................................................. 160
FP3: Casings should prevent users from accessing critical controls on the display unit, such as home or power buttons .................................................................................. 162
FP4: Casings should allow admin staff to easily access the display unit to access critical controls and to swap out the display unit ........................................................................ 162
Appendix A: Complete list of formative findings

FP5 Casings should support ad-hoc deployment by affording easy mounting and unmounting of SOLs .......................................................... 162
FP6 SOLs should provide dynamic control over display styles and parameters to adjust to different casings and environments .......................... 162
FP7 SOLs should support multiple methods to connect a mobile device to cater for users preferences and technical capabilities ........................................ 162
FP8 SOLs should streamline in the interaction and avoid unnecessary confirmation screens after content submission ................................. 162
FP9 SOLs should be unobtrusive and blend into the gallery environment .......... 165
FP10 SOLs should look polished and professional to instil confidence in their interactivity ........................................................................... 165
FP11 SOLs should support multiple networking technologies, including WiFi and 3G ....................................................................................... 165
FP12 SOLs should not require visitors to install a mobile application in order to use them .......................................................................... 165
FP13 SOLs should automatically try to reconnect when a WiFi connection is dropped ..................................................................................... 167
FP14 SOLs should have an indicator for network status and signal strength .... 167
FP15 SOLs should provide a wide range of interaction methods and not rely on specific technologies, applications or social network membership. ................................................................. 167
FP16 SOLs should display suitable information to advertise their interactivity, explain the interaction and encourage engagement .............. 167

Findings from formative user-testing sessions (Chapter 8.4)  Page

FT1: Interaction screens should not rely on users to return the SOL to its default idle screen but time-out automatically after a certain period of inactivity. .... 193
FT2: Connection information (e.g. QR code, URL, hashtag) should be available in all screens where user interaction is anticipated, including in help screens explaining the interaction to first-time users. ........................................ 194
FT3: SOLs should provide a wide range of interaction methods and not rely on specific technologies, applications or social network membership. .... 194
FT4: Help screens should provide detailed information and have a highly optimised information architecture .................................................. 195
FT5: Provide visual clues that help users to distinguish between the interface and the user-generated content presented in the interface ................ 197
FT6: Provide visual clues that help users to recognise interactive elements ....... 197
Appendix A: Complete list of formative findings

FT7: Show supporting information when users touch screen elements that are not interactive. .......................................................... 197
FT8: Clearly label the primary interaction element ........................................ 197
FT9: Only use graphical symbols that are widely used and recognised. .......... 197
FT10: Show content immediately on the SOL after submission. .................... 197

Findings from co-design sessions (Chapter 8.4) Page

FC1: SOLs should use simple, compact casings unless there is a clear reason for more unconventional designs ........................................... 199
FC2: SOLs should display short prompts that avoid stating the obvious ............ 200
FC3: SOLs should show descriptive labels for screen elements whose purpose is not entirely clear ......................................................... 201
FC4: SOLs should use clean, uncluttered screen designs ................................ 201
FC5: SOLs should display an image of the exhibit when installed further away to make the connection clear to users ..................................... 201
FC6: SOLs should use traditional top-level domains in their Web address unless there is a compelling reason to use generic domains ......................... 202
FC7: When displaying a human-readable Web address (URL) on SOLs there is no need to include the scheme component (e.g. http://) ............................. 205
FC8: SOLs should use plain, direct and commonly used terminology ............... 205
Appendix B: Technical overview of SOL prototypes

B.1. Prototype 1

Prototype 1 with paper bezel, NFC tag and QR code (a), without bezel in admin mode (b) and display mode (c), and related mobile applications for administrators (d) and visitors (e, f)
Appendix B: Technical overview of SOL prototypes

Display

Proof of concept prototype:

- based on *Google Nexus 7* tablet computer (Figure a)
- technically a web page displayed in customised Android WebView container
- admin interface prompts users to enter object ID and press refresh (Figure b)
- doing so loads the live counter page (Figure c)

Casing

- none -

Backend

Server backend is rudimentary at this stage:

- standard LAMP stack (Linux, Apache, MySQL, PHP)
- REST API to query number of comments for object

Admin app

Basic functionality:

- create object IDs
- create related digital resources: image, description (Figure d)
- basic configuration options: poll frequency, display style

Visitor app

Basic functionality:

- browse list of comments (Figure e)
- submit comment (Figure f).

Evaluation

See section 8.2.1
Appendix B: Technical overview of SOL prototypes

B.2. Prototype 2

Prototype 2 with NFC tag and printed QR code (a) and custom casing (b). Trial at a public event at the University of Brighton (c) and mobile application (d, e).

SOL

Low fidelity prototype

- based on Motorola Xoom 10.1 tablet computer
- technically a web page displayed in customised Android WebView container
- support for custom fonts and colours
- support for pinch-and-zoom to fit display to viewport of casing

Casing

- wooden frame with Perspex front plate and printed bezel (Figure a)
- paper bezel resulting in a 8.5" x 1.5" viewport (Figure a)
- casing open at the back (Figure b) for access to the display unit
Appendix B: Technical overview of SOL prototypes

Backend

- bug fixes and small improvements
- otherwise same as prototype 1

Admin app

- bug fixes and small improvements
- otherwise same as prototype 1

Visitor app

- bug fixes and small improvements (Figure d, e)
- otherwise same as prototype 1

Evaluation

See section 8.2.2
B.3. Prototype 3

Prototype 3 with NFC tag and printed QR code (a) and plastic casing (b, c). The prototype was demoed at an international workshop (d) and a research seminar (e).
### SOL

**Low fidelity prototype**
- based on *Samsung Galaxy GS9000* mobile phone
- supports operation via WiFi and 3G mobile data networks
- display app and admin interface based on prototype 2
- minor bug fixes and improvements

**Casing**
- plastic casing with transparent front plate (Figure a, b, c)
- paper bezel resulting in a 3.5" x 0.5" viewport (Figure a)
- casing can be opened to access the display unit (Figure b, c)

**Backend**
- bug fixes and small improvements
- otherwise same as prototype 2

**Admin app**
- bug fixes and small improvements
- otherwise same as prototype 2

**Visitor app**
- bug fixes and small improvements
- otherwise same as prototype 2

**Evaluation**
See section 8.2.3
Appendix B: Technical overview of SOL prototypes

B.4. Prototype 4

Prototype 4 supporting comments and star ratings (a, b) and landscape and portrait layouts (a, b, c, d), with MDF casing (e), password-protected configuration screens (f, g, h) and updated admin (i) and visitor app (j, k, l).
Appendix B: Technical overview of SOL prototypes

SOL

High fidelity prototype

- E-ink display based on *Barnes & Noble Nook Simple Touch* e-reader (Figure e)
- Android version 2.1 / rooted
- native application optimised for e-ink screens (re-draws)
- introduces concept of "layouts" that have certain features and functionality
- supports portrait and landscape layouts (Figure a, b, c, d)
- supports commenting and star rating layouts (Figure a, b)
- protected admin functionality (Figure f)
- supports poll, push and localhost networking modes (see Appendix C)
- configuration options (Figure g, h) include:
  - object registration
  - selection of networking mode
  - selection of screen layout
  - technical logs to diagnose problems
- generates QR code based on object ID, networking mode and contribution type
- asynchronous communicates with backend REST API

Casing

- casing made from laser-cut MDF (Medium-Density Fibreboard)
- supports secure mounting on the back plate (Figure e)
- removable bezel fixed with large bolts (Figure e)
- can be opened to swap out display unit after installation

Backend

```
<table>
<thead>
<tr>
<th>hosts</th>
<th>campaigns</th>
<th>objects</th>
<th>comments</th>
<th>users</th>
</tr>
</thead>
<tbody>
<tr>
<td>id</td>
<td>id</td>
<td>id</td>
<td>id</td>
<td>id</td>
</tr>
<tr>
<td>user</td>
<td>campaign</td>
<td>object</td>
<td>id_object</td>
<td>email</td>
</tr>
<tr>
<td>pass</td>
<td>title</td>
<td>lat</td>
<td>id_user</td>
<td>password</td>
</tr>
<tr>
<td>name</td>
<td>logo</td>
<td>lon</td>
<td>flag</td>
<td>nickname</td>
</tr>
<tr>
<td>logo</td>
<td>slug</td>
<td>image</td>
<td>stars</td>
<td>image</td>
</tr>
<tr>
<td>holiday</td>
<td>hashtag</td>
<td>label</td>
<td>comment</td>
<td></td>
</tr>
<tr>
<td>month</td>
<td>Homepage</td>
<td>homepage</td>
<td>modified</td>
<td></td>
</tr>
<tr>
<td>homepage</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>moderators</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
```

*Database schema used in prototype 4*
Appendix B: Technical overview of SOL prototypes

Still based on standard LAMP stack (Linux, Apache, MySQL, PHP) and providing a REST API for SOLs to query information, however, the database (see above) and REST API now offer support for:

- multiple host organisations, exhibitions ("campaigns") and objects
- technical user IDs and optional profile information
- comments, comment moderation and star ratings
- custom logos and web links for host organisations, exhibitions and objects
- RSS syndication and social media integration
- Google Cloud Messaging
- energy saving features in SOLs based on gallery opening hours and holidays

Admin app

Basic functionality with bug fixes and slight improvements over previous versions.

- create object IDs and related digital resources: image, description (Figure i)
- no interface for creating digital resources for hosts and exhibitions

Visitor app

Extended functionality with bug fixes and slight UI improvements over previous versions.

- support for star ratings (Figure j)
- browse list of comments (Figure k)
- submit comment (Figure l).

Evaluation

See section 8.2.4
Appendix B: Technical overview of SOL prototypes

B.5. Prototype 5

Prototype 5 (a) with configuration screen (b), admin app (c, d) and visitor app (e, f, g, h)
Appendix B: Technical overview of SOL prototypes

SOL

Further improved on prototype 4 with additional display and configuration options:

- human-readable, shortened Web address below QR code to support mobile connection via manual URL input (Figure a)
- notification icons for low battery and loss of network connection (Figure a)
- set up WiFi directly from configuration screen (Figure b)
- display SOL ID and WiFi connection status in configuration screen (Figure b)

Casing

- custom casing made by SGD to fit with exhibition environment (Figure a)
- supports various mounting options
- bezel is fixed with adhesive tape
- allows display unit to be swapped out after installation

Backend

Extended functionality and API:

- API for flagging comments for moderation
- Automatic notification emails to list of moderators
- One-click response to unlock or permanently hide flagged comments

Admin app

Minor improvements on prototype 4:

- resize uploaded object images for optimised display in admin app (Figure c, d)
- display object IDs in admin app browse and detail views (Figure c, d)

Visitor app

Extended functionality with bug fixes and UI improvements.

- context menu for flagging, editing and sharing comments (Figure g)
- out-bound social media integration (Figure g)
- flag comments with message to moderator (Figure h)
- unique, persistent user icons from gravatar.com (Figure e)

Evaluation

See section 8.3 Field trial 1: Fail Better
B.6. Prototype 6

Prototype 6 supporting direct touchscreen interaction (a, b, c). Design variations (d), casing for integration with gallery-mockup (e) and casing with slanted interaction surface (f, g, h)
Appendix B: Technical overview of SOL prototypes

SOL

Substantial redesign based on findings from *Fail Better* (Chapter 8):

- support for direct touchscreen interaction in addition to mobile interaction
- idle screen without connection information (Figure a)
- browse screen with connection information (Figure b)
- help screen with information how to connect mobile (Figure c)
- design variations for presentation of connection information (Figure d)
- code optimisations for e-ink screen rendering performance and quality
- retrieve/cache comments and meta data for exhibit to support content browsing

Casing

- modular cardboard casing (Figure d) that slots into the gallery mock-up for user-testing sessions (Chapter 8)
- MDF casing with slanted front to support touchscreen interaction (Figure e)
- removable bezel to swap out display unit
- openings at back for power cable (Figure f)
- fixings for mounting on horizontal and vertical surfaces (Figure f)

Backend

Extended functionality and API:

- retrieve/cache comments and meta data for exhibit to support content browsing

Admin app

Minor bug fixes, otherwise same as in prototype 5

Visitor app

Minor bug fixes, otherwise same as in prototype 5

Evaluation

See section 8.4 Formative user-testing and co-design
B.7. Prototype 7

Prototype 7 with and without support for on-screen content browsing (a, b). Configuration screen (c), slanted casings for integration with Home\Sick (d), styled mobile application (e, f, g, h) and admin dashboard supporting authentication (i), status overview (j) and digital asset creation (k, l).
Appendix B: Technical overview of SOL prototypes

SOL

Substantial redesign based on findings from *Fail Better* (Chapter 8) involving prototype 5 and formative user-testing and co-design sessions (Chapter 8) involving prototype 6:

- re-designed idle / browse / help screens (Figure a, b)
- support for designs with / without content browsing (Figure a, b)
- support for custom terminology (comments, ideas, fails, etc.)
- timeouts for browse and help screens to revert to idle screen
- enable/disable analytics data collection in configuration screen (Figure c)
- re-designed notifications for battery status and signal strength (Figure c)
- record and report analytics data (in addition to technical logging)
- report battery status, regularly ping server to detect loss of network connection
- support for remote/timed layout switching

Casing

- custom casing made by SGD to fit with exhibition environment (Figure d)
- slanted front to support touchscreen interaction
- openings at back for power cable and swapping out display
- supports mounting on horizontal and vertical surfaces

Backend

![Database schema used in prototype 7](image)

- 338 -
Appendix B: Technical overview of SOL prototypes

Substantial development compared to previous versions:

- extended database schema (see above)
- support for multiple exhibitions per host
- object-level customisation of terminology (comments, ideas, fails, etc.)
- store, manage and visualise analytics data
- optimised Twitter API polling across campaigns
- support for binary comment ratings
- support for dynamic comment ranking based on ratings and recency

Admin app

Substantial development compared to previous versions

- user authentication
- admin dashboard with real-time SOL status information
- direct access to submitted content
- mint object IDs, create and edit digital assets
- object-level customisation of terminology (comments, ideas, fails, etc.)
- interface for real-time data analytics and visualisation (see 8.5.3.3)

Visitor app

Substantial development compared to previous versions

- re-designed comment context menu
- removed out-bound social network integration
- support for comment rating functionality
- exhibition-level custom CSS to adapt look and feel to exhibition design

Evaluation

See section 8.5 Field trial 2: Home\Sick

---

Based on a modified version of the Reddit ranking algorithm: 

\[ f(n, t) = \log_{10}(n + 1) \times \text{sgn}(n) + \frac{45000}{t^2} \]

Ensures that newly submitted comments are always be on top for a short period, so that contributors see it showing up instantly, and then slowly sink down in the ranking as the rating component becomes more dominant. See Springer, M. (2013). The Mathematics of Reddit Rankings, or, How Upvotes Are Time Travel. Available: https://web.archive.org/web/20150426024231/http://scienceblogs.com/builtonfacts/2013/01/16/the-mathematics-of-reddit-rankings-or-how-upvotes-are-time-travel/. Retrieved 26 Apr 2015
C.1 Simple Poll

### Characteristics
- Tag (ID) is registered to an object (OID) on setup.
- Tag makes its ID available to the app and periodically polls the server to get current data (for the related OID).
- App reads the ID from the tag and communicates with the server to read current data and post new data for the related object.

<table>
<thead>
<tr>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>+ simple to implement</td>
<td>- wastes battery and bandwidth</td>
</tr>
<tr>
<td>+ access to internet is the only requirement</td>
<td>- high latency</td>
</tr>
</tbody>
</table>
## C.2 Push notifications

![Diagram of push notifications](image)

<table>
<thead>
<tr>
<th>Characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Tag (ID) is registered to an object (OID) on setup.</td>
</tr>
<tr>
<td>• Tag is registered for GCM (Google Cloud Messaging)</td>
</tr>
<tr>
<td>• Tag makes its ID and the server URL available, e.g.</td>
</tr>
<tr>
<td><a href="http://itrg.brighton.ac.uk/ubinote/app.php?id=1">http://itrg.brighton.ac.uk/ubinote/app.php?id=1</a></td>
</tr>
<tr>
<td>• App reads the ID from the tag</td>
</tr>
<tr>
<td>• App reads comment data from the server via HTTP GET</td>
</tr>
<tr>
<td>• App posts new content to the server via HTTP POST</td>
</tr>
<tr>
<td>• Server pushes a GCM UPDATE message to the tag, which then polls the server for current values (alternatively, the server directly sends up to 1kb aggregate data to the tag, which eliminates the need for a request to the server)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>+ no polling required</td>
<td>- requires Android 2.3 or higher</td>
</tr>
<tr>
<td>+ easy on battery and bandwidth</td>
<td>- unpredictable latency (usually around 0.5 sec, but can reach 30 sec or break down completely)</td>
</tr>
<tr>
<td>+ works with any kind of internet connection</td>
<td></td>
</tr>
</tbody>
</table>
C.3 Localhost / callback

** Characteristics **
- Tag (ID) is registered to an object (OID) on setup.
- Tag runs a web server on the local WiFi
- Tag makes its ID, IP:Port and the server URL available, e.g. http://itrg.brighton.ac.uk/ubinote/app.php?id=1&local=192.0.168.8:8080
- App reads the ID and IP:Port address from the tag
- App reads comment data from the server via HTTP GET
- App posts new content to the server via HTTP POST and notifies the tag (local host) to refresh the tag

** Advantages **
+ low latency, direct feedback
+ no polling required
+ easy on battery and bandwidth
+ no caching / sync required

** Disadvantages **
- only works when mobile is connected to same WiFi network as tag; WiFi must be set up to accept connections (most are)
C.4 Localhost / relay

Characteristics

- Tag (ID) is registered to an object (OID) on setup.
- Tag runs a web server on the local WiFi
- Tag makes its IP:Port address available, e.g. http://192.0.168.8:8080
- App reads the IP:Port address from the tag
- App reads comment data from the tag via HTTP GET
- App posts new content to the tag via HTTP POST
- Tag forwards all calls to the server and returns the results to the app

<table>
<thead>
<tr>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>+ no polling required</td>
<td>- only works when mobile is connected to same WiFi network as tag; WiFi must be set up to accept connections (most are)</td>
</tr>
<tr>
<td>+ easy on battery and bandwidth</td>
<td></td>
</tr>
<tr>
<td>+ no caching / sync required</td>
<td></td>
</tr>
<tr>
<td>+ no 3G for mobile required</td>
<td></td>
</tr>
</tbody>
</table>
C.5 Localhost / cache

**Characteristics**
- Tag (ID) is registered to an object (OID) on setup.
- Tag runs a web server on the local WiFi network.
- Tag loads comment data for object from the server via TID and keeps a local copy.
- Tag makes its IP:Port address available, e.g. http://192.0.168.8:8080.
- App reads the IP:Port address from the tag.
- App reads comment data from the tag via HTTP GET.
- App posts new content to the tag via HTTP POST, which updates the display and returns count.
- Tag asynchronously / periodically syncs data with the server.

<table>
<thead>
<tr>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>+ low latency, direct feedback</td>
<td>- only works when mobile is connected to same WiFi network as tag; WiFi must be set up to accept connections (most are)</td>
</tr>
<tr>
<td>+ no polling required</td>
<td>- requires local caching of data and synchronisation with the server</td>
</tr>
<tr>
<td>+ easy on battery and bandwidth</td>
<td></td>
</tr>
<tr>
<td>+ no 3G for mobile required</td>
<td></td>
</tr>
</tbody>
</table>
C.6 Overview of characteristics and usability implications

Overview of technical and usability implications of the different networking models presented in previous sections:

<table>
<thead>
<tr>
<th>SOL update</th>
<th>Simple poll</th>
<th>Push</th>
<th>Localhost / callback</th>
<th>Localhost / relay</th>
<th>Localhost / cache and sync</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Periodically request updates from server</td>
<td>Request updates from server after receiving push notification</td>
<td>Request updates from server on start-up and after submit to localhost</td>
<td>Request updates from server on start-up and after submit to localhost</td>
<td>Request updates from server on start-up, then handle everything locally. Sync with server in background.</td>
</tr>
</tbody>
</table>

| Latency of displaying a new comment | Variable, depends on poll frequency and network speed | Variable, depends on push latency and network speed | Medium, depends on network speed | Medium, depends on network speed | Low |

| Visitor read | Request data from server | Request data from server | Request data from server | Request data from SOL localhost | Request data from SOL localhost |

| Visitor post | Post data to server | Post data to server | Post data to server | Post data to SOL localhost | Post data to SOL localhost |

| WiFi SOL | Required | Required | Required | Required | Required |

| WiFi Mobile | Optional (can use 3g instead) | Optional (can use 3g instead) | Required (access localhost) | Required (access localhost) |

| Power profile | High (1-2 days on battery) | Economic (5-7 days on battery) | Economic (5-7 days on battery) | Economic (5-7 days on battery) |

| Effect of Wifi down | Read: 3g Post: 3g Update: fail | Read: 3g Post: 3g Update: fail | Read: 3g Post: fail Update: fail | Read: fail Post: fail Update: fail | Read: fail Post: fail Update: fail |

| Effect of network down | Read: 3g Post: 3g Update: fail | Read: 3g Post: fail Update: fail | Read: 3g Post: fail Update: fail | Read: fail Post: fail Update: fail | Read: fail Post: fail Update: fail |


| Notes | - Use WiFi or 3g - Possible costs for visitor for 3g - No WiFi signup required | - Use WiFi or 3g - Possible costs for visitors for 3g - No WiFi signup required - Requires Android v.2.3+ | - Use WiFi or 3g to read and post, but SOL updates only when content posted via WiFi - Possible costs for visitors for 3g - WiFi signup required to post (see above) | - No costs to visitor - WiFi signup required | - No costs to visitor - WiFi signup required |

Notes:
- Use WiFi or 3g
- Possible costs for visitor for 3g
- No WiFi signup required
- Requires Android v.2.3+
Appendix D: Instrument for museum visitor survey on commenting

Aims of the survey

Find out about museum visitors' preferences, expectations and conceptual models of commenting:

Preferences: What commenting mechanisms (visitor book, comment card, online, etc.) do visitors know? Which ones do they prefer for reading/writing comments and why?

Models and Motivations: What happens to a comment submitted to a museum? Who reads it? Does it make a difference?

Conservation: For how long are various forms of comments (visitor book, comment card, online, etc.) kept by the institution? In what form (digital/physical)?

Accountability: How are decisions made on selecting comments for promotion (e.g. display in gallery) or demotion (e.g. remove from comment board)? Who is involved in these decisions?

Ownership, IP: Can the museum remEDIATE (e.g. digital/physical) visitor comments and reuse them in other contexts (e.g. marketing materials)? Have visitors a say in such issues?

Checklist

- Interview script
- Illustration cards
- n * Participant Information Sheet
- n * Consent Form
- n * Survey instrument
- Location description form
- Response tally form
- Contact form
- Name tag, cards
- Clipboard, Pens
- Folder to collect interview notes
Appendix D: Instrument for museum visitor survey on commenting

Participant Information Sheet

What happens to visitor comments in museums and galleries?

Researcher: Marcus Winter
Project Title: Digital Signage for Ubiquitous Annotation: Developing Design Principles

Invitation

You are being invited to take part in a research study. Before you decide it is important for you to understand why the research is being done and what it will involve. Please take time to read the following information carefully. Talk to others about the study if you wish.

Please ask the researcher if there is anything that is not clear or if you would like more information. Take time to decide whether or not you wish to take part.

What is the purpose of the interview?

The research develops new technologies that can be used by museums visitors to comment on artworks and exhibits. To inform the design process, we need to learn what museums visitors think of existing commenting mechanisms such as visitor books and comment cards.

Why have I been chosen?

You are being asked to take part in the research because you are visiting a museum and might have views on commenting mechanisms in such places.

Do I have to take part?

It is up to you to decide whether or not to take part. If you do, you will be given this information sheet to keep and be asked to sign a consent form. You are still free to withdraw at any time and without giving a reason.

What will happen to me if I take part?

If you agree to take part, you will be asked to answer some questions about to your thoughts and experiences with commenting mechanisms used in museums and galleries.

The interview will take about 15-20 minutes.

What are the possible disadvantages and risks of taking part?

The interview does not involve any risk of physical or mental harm.
Appendix D: Instrument for museum visitor survey on commenting

What are the possible benefits of taking part?

There are no immediate benefits for you when taking part in the interview. However, you might find the experience interesting and, if you wish, will be notified about results of the study.

What will happen if I don’t want to carry on with the study?

You are free to withdraw from the interview at any time without giving any reason. Any information you provided before your decision to withdraw will be deleted.

Will my taking part in this study be kept confidential?

All information collected in this interview will be kept strictly confidential.

The data will be stored in a secure area and not be made available outside the context of this research. It will be held as long as necessary for the research and destroyed thereafter.

What will happen to the results of the research study?

Results of the research may be presented at academic conferences and in academic journals. In some cases the researcher may wish to include verbatim quotes in reports or publications. If this is the case, quotes will be anonymous and you will not be able to be identified.

If you wish to be notified about results, please get in touch with the researcher, who will be happy to provide you with copies of published materials.

What if there is a problem?

If you have any problems or complaints regarding the research you may want to discuss them in first place with the researcher.

If you are not satisfied that your concerns are dealt with appropriately, please contact the Doctoral College Centre for Science and Engineering at the University of Brighton.

Contact Details

Marcus Winter (Researcher)  
602 Watts Building, Moulsecoomb, Brighton BN2 4GJ  
telephone: +44 (0)1273 642476  
email: marcus.winter@brighton.ac.uk

Doctoral College Centre for Science and Engineering  
211 Mithras House, Moulsecoomb, Brighton BN2 4AT  
telephone: +44 (0)1273 641104 or 641105 or 641108  
email: s.jenkins@brighton.ac.uk
Appendix D: Instrument for museum visitor survey on commenting

Consent Form

What happens to visitor comments in museums and galleries?

**Researcher:** Marcus Winter  
**Project Title:** Digital Signage for Ubiquitous Annotation: Developing Design Principles

**Consent**

1. I agree to be involved in this research which investigates design aspects of dynamic touchpoints for attaching digital information to physical objects. I give my permission for the researcher to use excerpts from the interview for his research.

2. The researcher has explained the research to my satisfaction. I have been informed of the nature and purposes of the study and have read the information sheet. I understand the principles and processes of the study.

3. I am aware that I will be asked to take part in an interview discussing my views on commenting systems in museums and galleries.

4. I understand that my personal details will remain confidential. Data will be stored in a secure area, not be made available outside the context of this research and will be held only as long as necessary for the research.

5. I understand that my participation is voluntary and that I am free to withdraw at any time without giving any reason.

6. I understand that the data collected will be used as part of a research project. I understand that results of the research might be presented at academic conferences and in academic journals.

7. I agree to take part in the above study.

<table>
<thead>
<tr>
<th>Name of Participant</th>
<th>Date</th>
<th>Signature</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Name of Person taking consent (if different from researcher)</th>
<th>Date</th>
<th>Signature</th>
</tr>
</thead>
</table>

Marcus Winter  
**Researcher**

Date | Signature
Appendix D: Instrument for museum visitor survey on commenting

Interview Script

1. Hello I'm from the University of Brighton, would you have a few minutes to answer some questions? [follow sampling method]

2. My name is ...

3. I'm working on a research project which develops new technologies for feedback and commenting in museums and galleries.

4. I'd like to ask you some questions on commenting in museums and galleries.

5. Do you prefer doing the interview here or would you rather sit down? [if standing...]

6. Before we start, I'd like you to understand what the research is about.
   - Here's an information sheet and a consent form. [info + consent form]
   - Please take a few minutes to read this, I can read it to you if you prefer.
   - If anything is unclear, please ask.
   - If you agree to take part then sign here. [point out where to sign]

7. Thank you! [check consent form, put away]

8. I'd like to start with a few background questions...

9. Thank you for your time! [put away notes]

10. Do you have any additional comments or questions?

11. If you'd like to stay in touch or get notified about the results of this survey, please leave your name and email address here. This is not linked to your interview data, which will remains anonymous! [contact form]

12. Thanks again! [participant leaves]

13. Go over notes immediately, clarify, amend, ensure readability

14. Update response rate tally

Survey: What happens to visitor comments in museums and galleries? Marcus Winter, University of Brighton
Appendix D: Instrument for museum visitor survey on commenting

1) Background

"I'd like to go over the first part quite quickly..."

- What brought you here today?
  - facilitator
  - explorer
  - professional/hobbyist
  - recharger
  - experience seeker

- Do you often visit places like this? How often on average?
  - per week
  - per month
  - per year
  - every ________ weeks / months / years

- Do you usually come on your own or with friends or family?
  - own
  - friends or family
  - both

- Do you read labels for exhibits that interest you?
  - always
  - often
  - sometimes
  - rarely
  - never

- Do you talk with friends or family about the exhibition...
  - while in the exhibition space?
  - afterwards (e.g. in museum's cafe)?
  - later on (e.g. evening or following days)?

- Do you talk with other visitors in the museum about the exhibition?
  - always
  - often
  - sometimes
  - rarely
  - never

- Do you talk with museums personnel (if present) about the exhibition?
  - always
  - often
  - sometimes
  - rarely
  - never

- Do you tweet, blog or otherwise talk online about the exhibition...
  - while in the exhibition space?
  - afterwards (e.g. in museum's cafe)?
  - later on (e.g. evening or following days)?

  - only if the social channel is advertised somewhere
  - I don't have a smartphone
  - only if free WiFi available
  - I'm not into this, it's a generation thing
### Appendix D: Instrument for museum visitor survey on commenting

#### 2) Preferences - mechanisms

<table>
<thead>
<tr>
<th>Preference</th>
<th>Mechanisms</th>
<th>Options</th>
</tr>
</thead>
<tbody>
<tr>
<td>a) Which of these commenting mechanisms ...</td>
<td></td>
<td>visitor book  comment card  feedback board  feedback screen  website  social media</td>
</tr>
<tr>
<td></td>
<td>... have you <strong>seen or heard of</strong> before?</td>
<td></td>
</tr>
<tr>
<td></td>
<td>... have you <strong>used</strong> before?</td>
<td></td>
</tr>
<tr>
<td>b) Are you aware of <strong>any other</strong> commenting mechanisms?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>c) Which of these mechanisms do you <strong>prefer</strong> and <strong>why</strong>?</td>
<td></td>
<td>visitor book  comment card  feedback board  feedback screen  website  social media</td>
</tr>
</tbody>
</table>

Is that the same for reading comments / making comments yourself?

#### 3) Preferences - content

<table>
<thead>
<tr>
<th>Preference</th>
<th>Content Type</th>
<th>Options</th>
</tr>
</thead>
<tbody>
<tr>
<td>a) Which <strong>type of comment</strong> ...</td>
<td></td>
<td>greetings  feedback  interpretation  contribution</td>
</tr>
<tr>
<td></td>
<td>... would you be most interested to <strong>read</strong>?</td>
<td></td>
</tr>
<tr>
<td></td>
<td>... would you be most likely to <strong>make yourself</strong>?</td>
<td></td>
</tr>
<tr>
<td>b) When reading a comment, would you be interested in the commenters ...</td>
<td></td>
<td>name  username  age  gender  background knowledge  other:</td>
</tr>
<tr>
<td>c) When commenting yourself, would you be willing to give your ...</td>
<td></td>
<td>name  username  age  gender  background knowledge  other:</td>
</tr>
<tr>
<td>d) If there is an opportunity, do you <strong>actually</strong> tend to ...</td>
<td></td>
<td>always  often  sometimes  rarely  never</td>
</tr>
<tr>
<td></td>
<td>read visitor comments?</td>
<td></td>
</tr>
<tr>
<td></td>
<td>write comments yourself?</td>
<td></td>
</tr>
</tbody>
</table>

Survey: What happens to visitor comments in museums and galleries?  Marcus Winter, University of Brighton
## Appendix D: Instrument for museum visitor survey on commenting

### 4) Audience and Impact

a) When someone submits a comment, who do you think should read it?

- [ ] director  
- [ ] senior curator  
- [ ] junior curator  
- [ ] panel/team  
- [ ] artist  
- [ ] other visitors

Do you think that's what actually happens?

b) Do you think comments make a difference? Do they have an impact?

### 5) Conservation

<table>
<thead>
<tr>
<th>Format</th>
<th>Option</th>
<th>Option</th>
<th>Option</th>
<th>Option</th>
<th>Option</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>indefinitely</td>
<td>ex. end</td>
<td>for:</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>read + bin</td>
<td>ex. end</td>
<td>for:</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>indefinitely</td>
<td>ex. end</td>
<td>for:</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

If you would venture a guess, for how long do you think comments are actually kept?

<table>
<thead>
<tr>
<th>Format</th>
<th>Option</th>
<th>Option</th>
<th>Option</th>
<th>Option</th>
<th>Option</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>indefinitely</td>
<td>ex. end</td>
<td>for:</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>read + bin</td>
<td>ex. end</td>
<td>for:</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>indefinitely</td>
<td>ex. end</td>
<td>for:</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

b) Do you think comments made in paper/book format are converted to a digital format at some point?

- [ ] yes  
- [ ] probably  
- [ ] don't know  
- [ ] probably not  
- [ ] no

c) When someone posts on the museum's social network site or uses the museum’s @handle or hashtag, do you think those comments are harvested and archived by the museum?

- [ ] yes  
- [ ] probably  
- [ ] don't know  
- [ ] probably not  
- [ ] no
### Appendix D: Instrument for museum visitor survey on commenting

#### 6) Accountability

<table>
<thead>
<tr>
<th>[point out pre- / post-moderation mechanisms]</th>
</tr>
</thead>
</table>

#### a) Do you think museums sometimes **suppress** or **remove** comments and feedback?
- [ ] no  
- [ ] yes

**What do you think would be museums' criteria for suppressing/removing comments?**
- [ ] offensive  
- [ ] reflects negatively on museum  
- [ ] overly critical  
- [ ] wrong  
- [ ] irrelevant  
- [ ] trivial

**Do you think that is OK?**

#### b) What would be good **criteria for promoting** / featuring comments?
- [ ] stimulating  
- [ ] alternative viewpoint  
- [ ] constructive criticism  
- [ ] provoking discussion  
- [ ] new information  
- [ ] reflect positively on museum  
- [ ] of value to other visitors

#### c) Who do you think **decides** whether comments get censored/removed/promoted?
- [ ] director  
- [ ] senior curator  
- [ ] junior curator  
- [ ] panel/team  
- [ ] artist  
- [ ] other visitors

**Do you think that is OK?**

#### d) What happens to comments that are removed or not shown?
- [ ] deleted  
- [ ] kept in special folder  
- [ ] same as other comments  
- [ ] don't know
Appendix D: Instrument for museum visitor survey on commenting

<table>
<thead>
<tr>
<th>7) IP / Ownership</th>
<th>“OK, we’re on the last page now”</th>
</tr>
</thead>
<tbody>
<tr>
<td>a) Is it OK for a museum to ...</td>
<td></td>
</tr>
<tr>
<td>[1] show a comment from a visitor book on their website?</td>
<td>y</td>
</tr>
<tr>
<td>[2] print a comment made online and put it on the wall in a gallery?</td>
<td>y</td>
</tr>
<tr>
<td>[3] use comments in marketing brochures?</td>
<td>y</td>
</tr>
<tr>
<td>[4] blow up a comment and show it on the side of the building?</td>
<td>y</td>
</tr>
<tr>
<td>[5] print a comment on a mug and sell it in the museum shop?</td>
<td>y</td>
</tr>
<tr>
<td>[6] use a comment in these ways if it was made 10 years ago?</td>
<td>y</td>
</tr>
<tr>
<td>□ not if it includes my name / if I can be recognised</td>
<td></td>
</tr>
<tr>
<td>□ there should be a notice when you submit the comment that it might be used like this</td>
<td></td>
</tr>
</tbody>
</table>

| b) Should you have the right to request removal? |
| □ yes □ no □ depends: |

| c) If there was a notice explaining how comments might be used, would that put you off from submitting a comment? |
| □ yes □ probably □ don't know □ probably not □ no □ depends: |

| d) Who do you think ... |
| ... should own comments submitted to a museum / gallery? |
| □ museum □ visitor □ both □ comment is in public domain |
| ... actually owns comments submitted to a museum / gallery? |
| □ museum □ visitor □ both □ comment is in public domain |

<table>
<thead>
<tr>
<th>8) Demographics</th>
<th>“Just some demographic information”</th>
</tr>
</thead>
<tbody>
<tr>
<td>a) Gender</td>
<td>□ Female □ Male □ Other</td>
</tr>
<tr>
<td>b) Age</td>
<td>□ 16-24 □ 25-34 □ 35-44 □ 45-54 □ 55-64 □ 65-74 □ &gt; 75</td>
</tr>
<tr>
<td>c) First language</td>
<td>□ English □ Other:</td>
</tr>
<tr>
<td>d) Do you have a mobile phone with internet and touch screen?</td>
<td>□ Yes □ No</td>
</tr>
<tr>
<td>e) Do you have any inside knowledge of museums or galleries?</td>
<td>□ Yes □ No</td>
</tr>
</tbody>
</table>
Appendix D: Instrument for museum visitor survey on commenting

Sampling Method

As the survey does not aim for quantitative demographic data but instead for qualitative data describing museum visitors’ thoughts and attitudes towards commenting, there is no need for probability sampling. Instead, the survey employs in-situ convenience sampling: it includes museums and gallery visitors most easily approached and willing to take part in a structured interview.

This method has several advantages in the context of this study:

- focusing on local or reasonably close museums and galleries keeps costs low
- including as many visitors as possible instead of disregarding some for methodological reasons maximises response rates

In order to maximise the range of views and insights, several aspects of the employed (non-probability) sampling method have been informed by common strategies to address biases in probability sampling.

With respect to coverage\(^1\), a range of different museums and galleries have been selected as they are likely to draw different audiences, including organisations of different sizes and environments (town, city, metro). Surveys are carried out on different days of the week, including work days, holidays and weekends, which are likely to vary in audience composition. In addition, interviewers record weather conditions as they might influence some audience segments’ inclination to visit or not.

With respect to visitor sampling, interviewers keep a response tally to document how many visitors were approached and which proportion agreed to take part in the interview\(^2\). As interviewers are equally likely to approach individuals and groups (while usually interviewing only one group member), visitors attending in groups might be proportionally under-represented in the survey\(^3\). While this has no bearing on the validity of the study, which seeks qualitative information instead of representative quantitative results, the information is recorded nonetheless to document the sample composition and support the interpretation and analysis of the collected data.

Guidelines for interviewers:

- Only approach visitors 16 years and older. If in doubt, ask!
- Approach as many visitors as possible
- If there is a choice, try to balance between
  - male/female,
  - individuals/groups
  - across different ages
- Keep a response tally

\(^1\) Coverage bias occurs when the sample deviates from the population due to differences between covered and non-covered units, e.g. households without telephones are a well-known source of coverage bias in telephone surveys.

\(^2\) Non-response bias occurs when the sample deviates from the population due to differences between respondents and non-respondents.

\(^3\) Selection bias occurs when some units have a differing probability of selection that is unaccounted for by the researcher, e.g. households with multiple phone numbers in a telephone survey.
### Location Description

Briefly describe the location in which the survey is carried out. **Take some photographs!**

<table>
<thead>
<tr>
<th>Museum/Gallery name:</th>
<th>museum</th>
<th>art gallery</th>
<th>mixed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Size:</td>
<td>small</td>
<td>medium</td>
<td>large</td>
</tr>
<tr>
<td>Activity:</td>
<td>quiet</td>
<td>medium</td>
<td>busy</td>
</tr>
<tr>
<td>Environment:</td>
<td>town &lt; 50k</td>
<td>city &lt; 500k</td>
<td>metro</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Date:</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Day of week:</td>
<td>Mo</td>
<td>Tue</td>
<td>Wed</td>
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<tr>
<td>Holiday:</td>
<td>□ public</td>
<td>□ school</td>
<td></td>
</tr>
<tr>
<td>Weather:</td>
<td>□ sunny</td>
<td>□ fair</td>
<td>□ cloudy</td>
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<tr>
<td>This is usually a</td>
<td>□ busy day</td>
<td>□ average day</td>
<td>□ quiet day</td>
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</table>

[ask museum employees]

<table>
<thead>
<tr>
<th>Start time:</th>
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<tbody>
<tr>
<td>End time:</td>
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</table>

Description of the location:
**Response Rate Tally**

Keep track of the number of people approached, declined etc. Use ↓↑ ||

<table>
<thead>
<tr>
<th>Approached by the researcher:</th>
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<table>
<thead>
<tr>
<th>Listened to verbal explanation:</th>
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<table>
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<tr>
<th>Read information sheet:</th>
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<table>
<thead>
<tr>
<th>Signed consent form:</th>
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<table>
<thead>
<tr>
<th>Completed interview:</th>
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<table>
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<tr>
<th>Offered contact details for follow-up:</th>
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Appendix D: Instrument for museum visitor survey on commenting

**Contact Form**

If you'd like to stay in touch / receive results

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<tr>
<th>Name</th>
<th>Email</th>
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</table>
Appendix D: Instrument for museum visitor survey on commenting

Comment Book

Comment Cards
Appendix D: Instrument for museum visitor survey on commenting

Feedback Boards

Online Comments

Queen Elizabeth II's coronation was watched on television by around 20 million people in the United Kingdom. It was one of the first mass media events.

Credits:
Image ©Michael Bennett-Levy, Early Technology
Video used under permission from YouTube user ‘Medeasbiggestfan’.

created by NationalMuseumsScotland

There are no comments
Appendix D: Instrument for museum visitor survey on commenting

Feedback Screen

 Shoot the Wrx: artist and film-maker Jeff Keen

Please use this touch screen to tell us what you think about the exhibition

Brighton & Hove Museums

Start

Social Network Comments

He might be 30 ft tall and be worth $100k, but you can get face-to-face with the clone. Visit the Museum http://www.3l.org

Why don’t more museums do this? RT @MuseumPlanning Love it Speed Dating at Science Museum London @scienceumuseum

Finally seeing robotic man before heading to Museum. Should’ve w/tone theory, @scienceumuseum w/7 others) RT

Making Sinn prog am looking at amazing machine Ada Lovelace worked on first engine with a memory @scienceumuseum

- 362 -
Appendix E: Instrument for interviews with museum professionals

Research study: Museum professional's views on Social Object Labels

Researcher: Marcus Winter

Invitation
You are being invited to take part in a research study. Please read this information carefully before taking part. Ask the researcher if anything is unclear or if you would like more information. Talk to others about the study if you wish.

What is the purpose of the study?
The research develops interactive social object labels, which enable museum visitors to comment on exhibits. To inform the design process, we need to test and discuss prototypes with potential users.

Why have I been chosen?
You are being asked to take part because you represent a potential target audience for the developed system.

Do I have to take part?
No - it is up to you to decide whether to take part in the study or not. If you decide to do take part, you can withdraw at any time and without giving a reason.

What will happen to me if I take part?
You will be asked to use a prototype and comment on your experience. You will also be asked about your thoughts on the current design and possible alternatives. The session will be video recorded, however, we only film your hands. The session takes 10 - 15 minutes.

What are the possible disadvantages and risks of taking part?
The session does not involve any risk of physical or mental harm.

What are the possible benefits of taking part?
There are no immediate benefits for you when taking part. However, you might find the experience interesting and, if you wish, will be sent a report of the study.
Appendix E: Instrument for interviews with museum professionals

What will happen if I don’t want to carry on with the study?
You are free to withdraw at any time without giving any reason. Any information you provided before your decision to withdraw will be deleted.

Will my taking part in this study be kept confidential?
Information collected in this session is anonymous and will be kept strictly confidential. The data will not be made available outside the context of this research. It will be held as long as necessary and destroyed thereafter.

What will happen to the results of the research study?
Results of the research may be presented at academic conferences and in academic journals. In some cases the researcher may wish to include verbatim quotes in reports or publications. If this is the case, quotes will be anonymous and you will not be able to be identified. If you wish to be notified about results, please get in touch. We will be happy to provide you with copies of published materials.

What if there is a problem?
If you have any problems or complaints regarding the research you may want to discuss them in first place with the researcher. If you are not satisfied that your concerns are dealt with appropriately, please contact the Doctoral College Centre at the University of Brighton (see below).

Contact Details

Marcus Winter (Researcher)
602 Watts Building, Moulsecoomb, Brighton BN2 4GJ
telephone: +44 (0)1273 642476
corpora: marcus.winter@brighton.ac.uk

Doctoral College Centre for Science and Engineering
211 Mithras House, Moulsecoomb, Brighton BN2 4AT
telephone: +44 (0)1273 641104 or 641105 or 641108
corpora: s.jenkins@brighton.ac.uk
Appendix E: Instrument for interviews with museum professionals

Research study: Museum professional's views on Social Object Labels

Researcher: Marcus Winter

Project Title: Social Object Labels

Consent

1. I agree to be involved in this research which develops social object labels. I give my permission for the researcher to use data collected in this study.

2. The researcher has explained the research to my satisfaction. I have been informed of the nature and purposes of the study and have read the information sheet. I understand the principles and processes of the study.

3. I understand that I will be asked to take part in an interview discussing my views on the requirements and design of social object labels, and that the interview will be audio recorded for evaluation purposes.

4. I understand that my personal details will remain confidential. Data will be stored in a secure area, not be made available outside the context of this research and will be held only as long as necessary for the research.

5. I understand that my participation is voluntary and that I am free to withdraw at any time without giving any reason.

6. I understand that the data collected will be used as part of a research project. I understand that results of the research might be presented at academic conferences and in academic journals.

7. I agree to take part in the above study.

Participant Name: ____________________________ Date: ____________________________ Signature: ____________________________

Marcus Winter

Researcher Name: ____________________________ Date: ____________________________ Signature: ____________________________

Expert Interviews

Marcus Winter, 27 March 2014

- 365 -
Interview Questions

Interviews take approx. 20 minutes and explore the following points:

1 - Moderation
   o how to deal with inappropriate content?
   o who takes care of moderation?

2 - Attribution
   o should comments include name, age, gender, etc.?
   o should people login? user profiles?

3 - Openness
   o integration with social networks, e.g. tweet button?
   o allow remote access? post comments from internet?

4 - Content
   o what happens to comments when the exhibition ends?
   o get IPR clearance for comments?
   o where to show IPR information?

5 - Backend requirements
   o API / RSS
   o control panel: browse / edit / delete content?

6 - Deployment, robustness / maintenance
   o how peripheral or prominent?
   o power supply?
   o casing?

7 - Any other points?
Appendix F: Instrument for formative user testing and co-design sessions

Formative user-testing and co-design sessions

Scope and purpose
The scope of the user testing and co-design sessions is to get feedback on concrete designs and to explore and prioritise design alternatives together with potential users. Their main purpose is to increase usability by ensuring that the system behaves as expected by users, provides the necessary functionality and uses appropriate interaction patterns, terminology and iconography when presenting information.

Methodology
Participatory design has been repeatedly shown to lead to more relevant and usable information systems (Gould and Lewis, 1985; Baroudi, Olson and Ives, 1986; Spinuzzi, 2005), however, it has also drawn criticism as being expensive, ineffective, encumbered by language problems and hindered by entrenched roles of users and developers (Beath and Orlikowski, 1994; Heinboekel et al., 1996). Some of the differences in how participatory methods are perceived may stem from applying them to different classes of problems. Donald Norman, a long-term advocate of user-centred design, distinguishes between incremental and radical innovation and in a recent paper and suggests that participatory methods are well suited for the former but less so for the latter (Norman and Verganti, 2014). Support for this view crops up repeatedly over time in both, academia and industry. Scaife et al. (1997) question the ability of stakeholders to contribute as equal partners in the software design process. Nielsen (1993) points out that “users are not designers” (pp. 12-13) and Steve Jobs of Apple Corporation is on record as saying that “it’s not the consumers’ job to figure out what they want”\footnote{Business Insider (2011). Available http://www.businessinsider.com/not-the-customers-job-to-know-what-they-want-2011-4}. A key argument often mentioned in this context is that users are able to find problems in existing designs but usually lack the technical overview to generate radically new ideas and the design skills to turn them into usable products.

Considering the potential benefits and limitations of participatory methods at this stage of the development process, the co-design sessions carefully balance between eliciting feedback on existing designs and enabling participants to contribute new ideas. Sessions are based on concrete working prototypes that give participants an overall idea of the developed system’s purpose, functionality and interaction. In addition, an assortment of paper prototypes is used to visualise possible design alternatives and provide a basis for participants to comment on, prioritise and develop their own ideas if they wish.

Sample
Recommended sample sizes for formative studies are based on Problem Discoverability [p], i.e. the likelihood of detecting a problem, and Problem Discovery Goal [P(x ≥ 1)], i.e. the likelihood that a problem is detected by at least one participant during the study. Sauro and Lewis (2012) relate these two variables in the following formula, which results in a recommended sample size when solved for n:

\[ P(x ≥ 1) = 1 - (1 - p)n \]
Appendix F: Instrument for formative user testing and co-design sessions

The co-design sessions aim to inform the research at a relatively coarse level and outcomes reflect to some degree personal preferences of participants, e.g. layout problems, preference for textual or icon buttons, etc. Based on this consideration, the study assumes a conservative Problem Discoverability of 15% (i.e. in 15% of cases participants will be able to spot a problem in the existing designs or to identify their preference for design alternatives). Similarly, given that the study is not carried out in a realistic environment and does not involve a fully developed design, an overly ambitious Problem Discovery Goal would be pointless at this stage. Aiming for a moderate Problem Discovery of 75% or more, Sauro and Lewis’ (ibid) formula suggests a sample size of at least nine participants:

\[ n \geq 9 \]

Participants will be recruited among staff and students at the University of Brighton. While there is no compelling need for the sample to be representative, the study aims to avoid bias by including both male and female participants and a range of age groups and ethnicities.

Checklist
- demo rig with SOL
- demo mobile with NFC reader and QR code scanner installed
- paper prototypes
- video camera
- tripod
- charger
- pens
- script
- n * demographics questionnaire
- n * co-design notes sheet
- n * SUS questionnaire
- n * information sheets
- n * consent forms
Appendix F: Instrument for formative user testing and co-design sessions

Research study: Co-designing Social Object Labels

Researcher: Marcus Winter
Project Title: Social Object Labels

Invitation
You are being invited to take part in a research study. Please read this information carefully before taking part. Ask the researcher if anything is unclear or if you would like more information. Talk to others about the study if you wish.

What is the purpose of the study?
The research develops interactive social object labels, which enable museum visitors to comment on exhibits. To inform the design process, we need to test and discuss prototypes with potential users.

Why have I been chosen?
You are being asked to take part because you represent a potential target audience for the developed system.

Do I have to take part?
No - it is up to you to decide whether to take part in the study or not. If you decide to do take part, you can withdraw at any time and without giving a reason.

What will happen to me if I take part?
You will be asked to use a prototype and comment on your experience. You also will be asked about your thoughts on the current design and possible alternatives. The session will be video recorded, however, we only film your hands. The session takes 10 - 15 minutes.

What are the possible disadvantages and risks of taking part?
The session does not involve any risk of physical or mental harm.

What are the possible benefits of taking part?
There are no immediate benefits for you when taking part. However, you might find the experience interesting and, if you wish, will be sent a report of the study.
Appendix F: Instrument for formative user testing and co-design sessions

What will happen if I don’t want to carry on with the study?
You are free to withdraw at any time without giving any reason. Any information you provided before your decision to withdraw will be deleted.

Will my taking part in this study be kept confidential?
Information collected in this session is anonymous and will be kept strictly confidential. The data will not be made available outside the context of this research. It will be held as long as necessary and destroyed thereafter.

What will happen to the results of the research study?
Results of the research may be presented at academic conferences and in academic journals. In some cases the researcher may wish to include verbatim quotes in reports or publications. If this is the case, quotes will be anonymous and you will not be able to be identified. If you wish to be notified about results, please get in touch. We will be happy to provide you with copies of published materials.

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telephone: +44 (0)1273 641104 or 641105 or 641108
e-mail: s.jenkins@brighton.ac.uk
Research study: Co-designing Social Object Labels

**Researcher:** Marcus Winter

**Project Title:** Social Object Labels

**Consent**

1. I agree to be involved in this research which develops interactive social object labels. I give my permission for the researcher to use data collected during the co-design session for his research.

2. The researcher has explained the research to my satisfaction. I have been informed of the nature and purposes of the study and have read the information sheet. I understand the principles and processes of the study.

3. I understand that I will be asked to take part in a co-design session discussing my views on existing designs and possible alternatives.

4. I understand that my personal details will remain confidential. Data will be stored in a secure area, not be made available outside the context of this research and will be held only as long as necessary for the research.

5. I understand that my participation is voluntary and that I am free to withdraw at any time without giving any reason.

6. I understand that the data collected will be used as part of a research project. I understand that results of the research might be presented at academic conferences and in academic journals.

7. I agree to take part in the above study.

<table>
<thead>
<tr>
<th>Participant</th>
<th>Date</th>
<th>Signature</th>
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<tbody>
<tr>
<td>Marcus Winter</td>
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<tr>
<th>Researcher</th>
<th>Date</th>
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<td>Marcus Winter</td>
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Co-designing Social Object Labels

Marcus Winter, 24 September 2014
### Appendix F: Instrument for formative user testing and co-design sessions

<table>
<thead>
<tr>
<th>Step</th>
<th>Materials / Questions</th>
<th>Outcomes</th>
<th>Time</th>
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<tr>
<td><strong>1) Introduction and Consent</strong>&lt;br&gt;Give participants a short introduction to the research and ask for consent.&lt;br&gt;--- Set up demo rig / video camera while participant reads and signs consent form.&lt;br&gt;--- Initialise video recording with participant number (on demographics form)</td>
<td>- Consent form&lt;br&gt;- Pen&lt;br&gt;- Information sheet&lt;br&gt;- Printed illustrations&lt;br&gt;- Video camera&lt;br&gt;- Demographics form</td>
<td>Informed consent&lt;br&gt;Demo rig and camera ready to go</td>
<td>2 min</td>
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| **2) Carry out user task**<br>"Have a go at the prototype, look at the comments and submit one yourself."
Speak out loud: "...and please comment aloud on what you think and do..."
--- use own mobile or the demo mobile | - Demo rig<br>- Demo phone<br>- Video camera (focus on prototype) | Video recording of user interaction with SOL.<br>Problems, preferences: interaction, terminology, icons, etc. | 2 min |
| **3) Discussion**<br>"What do you think? Does it make sense or is there anything you would change or improve?"
--- probe further as required: why? how? | - Demo rig<br>- Demo phone<br>- Video camera (focus on prototype) | Video (audio) recording of discussion.<br>Problems, preferences, possible solutions | 2 min |
| **4) Co-design**<br>"Here are some other designs I'm thinking about. Can we quickly go through them?"
--- train camera on focus patch<br>--- lay out design artefacts on focus patch<br>--- go through co-design topic list | - Paper prototypes<br>- Co-design topic list<br>- Scissors<br>- Focus patch<br>- Video camera (focus on patch) | Video recording and notes of co-design session.<br>Understand preferences, refine existing designs. | 5 min |
| **5) Wrap-up and demographics**<br>"Thanks very much ... Before you run off, could you just tick the boxes here?"
--- hand demographics form and pen | - Demographics form<br>- Pen | Demographics | 1 min |
| **6) Optional: SUS, HED-UT questionnaires**<br>"Thanks again, I really appreciate it..."
"If you like fill in a 2 minute questionnaire about the prototype - but only if you have time."
Pack up: camera, demo patch, etc. | - Questionnaires<br>- Pen | SUS score, HED-UT score<br>Baseline to compare with scores of later prototypes | 3 min |
Appendix F: Instrument for formative user testing and co-design sessions

<table>
<thead>
<tr>
<th>Participant No</th>
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<tr>
<td>1) Which casing do you prefer? (a) (b) (c) Other ideas?</td>
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<tr>
<td>2) Screen1: How to show number of comments? (d) (e) (f) (g) (h) (i) (j) Other ideas?</td>
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<tr>
<td>3) Screen1: User prompt touch</td>
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<td>4) Screen2: Add button: text</td>
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<td>5) Screen2: ubinote.com/16</td>
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<td>6) Screen3: URL representation (w1) (w2) (w3) (w4) Other ideas?</td>
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<td>7) Screen3: Terminology: Visit, Go to ... (w5) (w6) (w7) (w8) (w9) Other ideas?</td>
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<td>8) Screen3: Terminology: Use, Tweet, ... (w10) (w11) Other ideas?</td>
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<tr>
<td>9) Screen3: Terminology: QR code, barcode, code (w12) (w13) (w14) Other ideas?</td>
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<tr>
<td>10) Screen3: Terminology: Touch, Tap, Scan (w15) (w16) (w17) Other ideas?</td>
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<tr>
<td>11) Alternative: show options permanently? (yes) (no) Other ideas?</td>
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Appendix F: Instrument for formative user testing and co-design sessions

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- Gender -
- Male 
- Female 
- Trans* 
- Prefer not to say

- Age -
- 16-24 years 
- 25-34 years 
- 35-44 years 
- 45-54 years 
- 55-64 years 
- 65-74 years 
- 75+ years or more

- First language -
- English 
- Other:

- Do you have a mobile phone with Internet and touch screen? -
- Yes 
- No

- Have you ever scanned a QR code? -
- Yes 
- No

- Does your mobile phone have an NFC reader? -
- Yes 
- No 
- Not sure

- Do you use Twitter? -
- Yes 
- No

- How often do you visit museums and galleries? -
- Less often 
- 1-2 per year 
- 3-4 per year 
- More often
Appendix F: Instrument for formative user testing and co-design sessions

Using this commenting system in a museum or gallery would be ...

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<th>Slightly</th>
<th>Moderately</th>
<th>Quite</th>
<th>Extremely</th>
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<td>1. Useful</td>
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<td>2. Practical</td>
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<td>3. Functional</td>
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<td>4. Helpful</td>
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<td>5. Efficient</td>
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<td>6. Exciting</td>
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<td>7. Fun</td>
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<tr>
<td>8. Amusing</td>
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<td>9. Thrilling</td>
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<td>10. Cheerful</td>
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Short-Form HED / UT Scale [Opertsching and v.d. Heijden, 2004]

Usability

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<tr>
<th></th>
<th>Strongly Disagree</th>
<th>Disagree</th>
<th>Undecided</th>
<th>Agree</th>
<th>Strongly Agree</th>
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<tbody>
<tr>
<td>1. I think that I would like to use this system frequently</td>
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<td>2. I found the system unnecessarily complex</td>
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<td>3. I thought the system was easy to use</td>
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<tr>
<td>4. I think that I would need the support of a technical person to be able to use this system</td>
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<td>5. I found the various functions in this system were well integrated</td>
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<tr>
<td>6. I thought there was too much inconsistency in this system</td>
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<td>7. I would imagine that most people would learn to use this system very quickly</td>
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<td></td>
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</tr>
</tbody>
</table>

System Usability Scale © Digital Equipment Corporation, 1986
Appendix F: Instrument for formative user testing and co-design sessions
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Appendix F: Instrument for formative user testing and co-design sessions
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Paper prototypes

- Touch to read comments

- Touch screen to read comments
Appendix F: Instrument for formative user testing and co-design sessions

Paper prototypes

16 Comments

Touch screen or tap
Appendix F: Instrument for formative user testing and co-design sessions

Paper prototypes

16 Comments

Touch screen or tap

A winter swimmer at a lake near Novosibirsk

16 Comments

Touch screen or tap
Appendix F: Instrument for formative user testing and co-design sessions

A winter swimmer at a lake near Novosibirsk

16 Comments

Touch screen or tap

Joe Bloggs, 30 minutes ago
Aren’t people absolutely amazing? He could be sitting on his sofa having tea but instead jumps into an icy lake. Marvellous!
Appendix F: Instrument for formative user testing and co-design sessions

Joe Bloggs, 30 minutes ago

Aren't people absolutely amazing? He could be sitting on his sofa having tea but instead jumps into an icy lake. Marvellous!

add ubinote.com/16 #ubinote16

Joe Bloggs, 30 minutes ago

Aren't people absolutely amazing? He could be sitting on his sofa having tea but instead jumps into an icy lake. Marvellous!

add comment ubinote.com/16 #ubinote16
Appendix F: Instrument for formative user testing and co-design sessions

Joe Bloggs, 30 minutes ago
Aren't people absolutely amazing? He could be sitting on his sofa having tea but instead jumps into an icy lake. Marvellous!

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Appendix F: Instrument for formative user testing and co-design sessions

Paper prototypes

Joe Bloggs, 30 minutes ago
Aren’t people absolutely amazing? He could be sitting on his sofa having tea but instead jumps into an icy lake. Marvellous!

[Image of paper prototype]

Joe Bloggs, 30 minutes ago
Aren’t people absolutely amazing? He could be sitting on his sofa having tea but instead jumps into an icy lake. Marvellous!

[Image of paper prototype]
Appendix F: Instrument for formative user testing and co-design sessions

Joe Bloggs, 30 minutes ago
Aren't people absolutely amazing? He could be sitting on his sofa having tea but instead jumps into an icy lake. Marvellous!

ubinote.com/16  #ubinote16
Appendix F: Instrument for formative user testing and co-design sessions

Paper prototypes

Joe Bloggs, 30 minutes ago
Aren't people absolutely amazing? He could be sitting on his sofa having tea but instead jumps into an icy lake. Marvellous!

Co-designing Social Object Labels
Marcus Winter, 24 September 2014
Appendix F: Instrument for formative user testing and co-design sessions

Joe Bloggs, 30 minutes ago
Aren't people absolutely amazing? He could be sitting on his sofa having tea but instead jumps into an icy lake. Marvellous!

add ubinote.com/16
#ubinote16

dislike

Joe Bloggs, 30 minutes ago
Aren't people absolutely amazing? He could be sitting on his sofa having tea but instead jumps into an icy lake. Marvellous!

add ubibuzz/16
#ubibuzz16

dislike
Appendix F: Instrument for formative user testing and co-design sessions

1) Visit http://www.ubinote.com/16
2) Visit http://ubinote.com/16
3) Visit www.ubinote.com/16
4) Visit ubinote.com/16
5) Visit <web address>
6) Go to <web address>
7) Browse to <web address>
8) Navigate to <web address>
9) Point your browser to <web address>
10) Use hashtag #ubinote16
11) Tweet hashtag #ubinote16
12) Scan the QR code
13) Scan the barcode
14) Scan the code
15) Touch the NFC tag
16) Tap the NFC tag
17) Scan the NFC tag
Appendix F: Instrument for formative user testing and co-design sessions

Paper prototypes

Joe Bloggs, 30 minutes ago

Aren't people absolutely amazing? He could be sitting on his sofa having tea but instead jumps into an icy lake. Marvellous!
Appendix G: Instrument for empirical evaluation 1: Fail Better

Aims of the study

Find out about gallery visitors' awareness and mental models of Social Object Labels (SOLs):

Awareness:
- Do visitors look at the object, read the object label, notice the SOL?
- Do they recognise it is interactive?
- Do they understand its nature and purpose?

Models and Motivations:
- If visitors notice a SOL and realise it's interactive
  - How do they think it works?
  - What do they think they get when they scan it?
  - Would they expect to add their own comments?
- If visitors scanned a SOL
  - Did they get what they expected? Was it worth scanning it?
  - If they did not scan it
    - What would motivate them to scan it?

Instruments

- Observations
- Visitor interviews
- System Usability Scale

Checklist

☐ Visitor interview script
☐ m * Observation coding form
☐ m * Observation free codes
☐ n * Participant Information Sheet
☐ n * Consent Form
☐ n * Interview coding form
☐ n * System Usability Scale
☐ Contact form
☐ Name tag, cards
☐ Clipboard, Pens
☐ Folder to collect observation and interview notes
Appendix G: Instrument for empirical evaluation 1: Fail Better

Sampling Method

As the survey does not aim for quantitative demographic data but instead for qualitative data describing visitors’ awareness and mental models of SOLs, there is no need for probability sampling. Instead, the survey employs in-situ convenience sampling: it includes gallery visitors most easily approached and willing to take part in a structured interview. Including as many visitors as possible instead of disregarding some for methodological reasons maximises response rates.

In order to maximise the range of views and insights, several aspects of the employed (non-probability) sampling method have been informed by common strategies to address biases in probability sampling.

With respect to coverage\(^1\), the surveys are carried out on both a traditional work day (Friday) and the weekend (Saturday), which are likely to vary in audience composition.

With respect to visitor sampling, the interviewer keeps a response tally to document how many visitors were approached and which proportion agreed to take part in the interview\(^2\). As the interviewer is equally likely to approach individuals and groups (while usually interviewing only one group member), visitors attending in groups might be proportionally under-represented in the survey\(^3\). While this has no bearing on the validity of the study, which seeks qualitative information instead of representative quantitative results, the information is recorded nonetheless to document the sample composition and support the interpretation and analysis of the collected data.

Guidelines for the interviewer:

- Only approach visitors 18 years and older. If in doubt, ask!
- If there is a choice, try to balance between
  - male/female,
  - individuals/groups
  - across different ages
- Keep a response tally

---

\(^1\) Coverage bias occurs when the sample deviates from the population due to differences between covered and non-covered units, e.g. households without telephones are a well-known source of coverage bias in telephone surveys.

\(^2\) Non-response bias occurs when the sample deviates from the population due to differences between respondents and non-respondents.

\(^3\) Selection bias occurs when some units have a differing probability of selection that is unaccounted for by the researcher, e.g. households with multiple phone numbers in a telephone survey.
Participant Information Sheet

Social Object Annotation

Researcher: Marcus Winter
Project Title: Social Object Labels: Developing Design Principles

Invitation
You are being invited to take part in a research study. Please read the following information before you decide to take part. Talk to others about the study if you wish and ask the researcher if there is anything unclear or if you would like more information.

What is the purpose of the interview?
The research develops new technologies for commenting and feedback in museums and galleries. To inform the design process, we need to know what visitors think about our current prototype.

Why have I been chosen?
You are being asked to take part in the research because you are visiting the Science Gallery Dublin and might have noticed or interacted with our current prototype.

Do I have to take part?
You do not have to take part and you are free to withdraw at any time and without giving a reason. If you do take part, you will be asked to sign a consent form.

What will happen to me if I take part?
You will be asked some questions about your experience in the gallery and your thoughts on our current prototype. The interview will take about 5 minutes.

What are the possible disadvantages and risks of taking part?
The interview is anonymous and does not ask any personal questions.

What are the possible benefits of taking part?
You might find the experience interesting and, if you wish, will be notified about results of the study.

What will happen if I don’t want to carry on with the study?
You are free to withdraw from the interview at any time without giving any reason.

Will my taking part in this study be kept confidential?
All information collected in this interview will be kept strictly confidential. The data will be stored in a secure area and not be made available outside the context of this research. It will be held as long as necessary for the research and destroyed thereafter.

What will happen to the results of the research study?
Results of the research may be presented at academic conferences and in academic journals. In some cases the researcher may wish to include verbatim quotes in reports or publications. If this is the case, quotes will be anonymous and you will not be able to be identified.

What if there is a problem?
If you have any problems or complaints regarding the research please discuss them in first place with the researcher. If you are not satisfied that your concerns are dealt with appropriately, please contact the Doctoral College Centre SE at the University of Brighton (contact details overleaf).
Contact Details

Marcus Winter (Researcher)
602 Watts Building, Moulsecoomb, Brighton BN2 4GJ
telephone: +44 (0)1273 642476
email: marcus.winter@brighton.ac.uk

Doctoral College Centre for Science and Engineering
211 Mithras House, Moulsecoomb, Brighton BN2 4AT
telephone: +44 (0)1273 641104 or 641105 or 641108
email: s.jenkins@brighton.ac.uk
Consent Form

Social Object Annotation

Researcher: Marcus Winter
Project Title: Social Object Labels: Developing Design Principles

Consent

1. I agree to be involved in this research which investigates design aspects of Social Object Labels. I give my permission for the researcher to use excerpts from the interview for his research.

2. The researcher has explained the research to my satisfaction and I have read the information sheet. I understand the principles and processes of the study.

3. I am aware that I will be asked to take part in an interview discussing my experience in the gallery with regard to Social Object Labels.

4. I understand that the interview is anonymous and no personal information will be collected.

5. I understand that my participation is voluntary and that I am free to withdraw at any time without giving any reason.

6. I understand that collected data will be stored in a secure area and held only as long as necessary for the research. The data will not be made available outside the context of this research.

7. I understand that collected data will be used as part of a research project. I understand that results of the research might be presented at academic conferences and in academic journals.

8. I agree to take part in the above study.

__________________________________________________________________________
Name of Participant Date Signature

__________________________________________________________________________
Name of Person taking consent Date Signature
(if different from researcher)

__________________________________________________________________________
Marcus Winter Date Signature
Researcher
## Location Description

Briefly describe the location in which the survey is carried out. **Take some photographs!**

<table>
<thead>
<tr>
<th>Friday, 25 April 2014</th>
<th>Start time:</th>
<th>End time:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Description of the location:</td>
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<td></td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Saturday, 26 April 2014</th>
<th>Start time:</th>
<th>End time:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Description of the location:</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Appendix G: Instrument for empirical evaluation 1: Fail Better

Interview Script

1. Hello I'm from the University of Brighton, would you have a few minutes to answer some questions? [follow sampling method]

2. My name is …

3. I'm working on a research project which develops new technologies for feedback and commenting in museums and galleries.

4. I'd like to ask you some questions on your experience today at the Science Gallery.

   It will take about 4-5 minutes. Would that be ok? [if standing…]

5. Do you prefer doing the interview here or would you rather sit down? There are some chairs over there…

6. Before we start, I'd like you to understand what the research is about.
   - Here's an information sheet and a consent form. [info + consent form]
   - Please take a minute to read this. I can read it to you if you prefer.
   - If anything is unclear, please ask.
   - If you agree to take part then sign here. [point out where to sign]

7. Thank you! [check consent form, put away]

8. OK, let's jump right in…

   …follow survey instrument for with / without interaction….

9. Thank you for your time! [put away notes]

10. Do you have any other comments or questions?

11. If you'd like to stay in touch or get notified about the results of the research please leave your name and email address here. This is not linked to your interview data, which will remain anonymous! [contact form]

12. Thanks again! [participant leaves]

13. Go over notes immediately, clarify, amend, ensure readability

14. Update response rate tally
## Appendix G: Instrument for empirical evaluation 1: Fail Better

### People who did NOT interact with SOLs

"OK, let's jump right in..."

a) Did you notice the display next to `<exhibit>`?

- [ ] yes
- [ ] no

b) What would you think it is for?

- [ ] read comments
- [ ] write comments
- [ ] not sure

c) Would you think it's interactive?

- [ ] yes
- [ ] no
- [ ] not sure

d) How do you think it works?

- [ ] don't know
- [ ] use mobile phone
- [ ] need an app for it
- [ ] enter code
- [ ] scan QR code
- [ ] touch NFC tag

d) What kind of content would you expect when scanning it?

- [ ] don't know
- [ ] website
- [ ] info about exhibition/exhibit
- [ ] list of comments

c) Would you expect that you can enter your own comments?

- [ ] yes
- [ ] no

g) Did you ever scan a QR code / NFC tag?

- [ ] no, neither QR nor NFC
- [ ] yes, QR code
- [ ] yes, NFC tag

f) What would make you try it out?

### Demographics

"Maybe you'd like to fill this in yourself..."

<table>
<thead>
<tr>
<th>Gender</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th>Prefer not to disclose</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>[ ] Female</td>
<td>[ ] Male</td>
<td>[ ] Trans*</td>
<td>[ ]</td>
<td></td>
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<table>
<thead>
<tr>
<th>Age</th>
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<tr>
<td></td>
<td>[ ] 16-24</td>
<td>[ ] 25-34</td>
<td>[ ] 35-44</td>
<td>[ ] 45-54</td>
<td>[ ] 55-64</td>
<td>[ ] 65-74</td>
<td>[ ] 75+</td>
<td></td>
<td></td>
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</table>

<table>
<thead>
<tr>
<th>Do you have a mobile phone?</th>
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<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>[ ] no</td>
<td>[ ] yes, with:</td>
<td>Internet</td>
<td>Barcode scanner</td>
<td>NFC reader</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Appendix G: Instrument for empirical evaluation 1: Fail Better

**People who DID interact with SOLs**

"OK, let's jump right in..."

<table>
<thead>
<tr>
<th>q</th>
<th>Answer</th>
</tr>
</thead>
<tbody>
<tr>
<td>a)</td>
<td>When you first noticed the display (next to &lt;exhibit&gt;), what did you think it was for?</td>
</tr>
<tr>
<td></td>
<td>☐ read comments ☐ write comments ☐ not sure</td>
</tr>
<tr>
<td>b)</td>
<td>Was it clear to you from the start how it works?</td>
</tr>
<tr>
<td></td>
<td>☐ yes ☐ no</td>
</tr>
<tr>
<td>c)</td>
<td>Did you scan a QR code / NFC tag before?</td>
</tr>
<tr>
<td></td>
<td>☐ no, neither QR nor NFC ☐ yes, QR code ☐ yes, NFC tag</td>
</tr>
<tr>
<td>d)</td>
<td>What kind of content did you expect when scanning it?</td>
</tr>
<tr>
<td></td>
<td>☐ don't know ☐ website ☐ info about exhibition/exhibit ☐ list of comments</td>
</tr>
<tr>
<td>e)</td>
<td>Was it worth scanning it?</td>
</tr>
<tr>
<td></td>
<td>☐ yes ☐ no</td>
</tr>
<tr>
<td>f)</td>
<td>Would you scan it again (for another exhibit)?</td>
</tr>
<tr>
<td></td>
<td>☐ yes ☐ no</td>
</tr>
<tr>
<td>g)</td>
<td>Did you expect that you can add your own comments?</td>
</tr>
<tr>
<td></td>
<td>☐ yes ☐ no</td>
</tr>
<tr>
<td>h)</td>
<td>Did you add a comment?</td>
</tr>
<tr>
<td></td>
<td>☐ yes ☐ no</td>
</tr>
<tr>
<td>h.0)</td>
<td>Did it behave as you expected?</td>
</tr>
<tr>
<td></td>
<td>☐ yes ☐ no</td>
</tr>
<tr>
<td>h.1)</td>
<td>What would motivate you to add a comment?</td>
</tr>
</tbody>
</table>

**Demographics**

"Maybe you'd like to fill this in yourself..."

<table>
<thead>
<tr>
<th>q</th>
<th>Answer</th>
</tr>
</thead>
<tbody>
<tr>
<td>a)</td>
<td>Gender</td>
</tr>
<tr>
<td></td>
<td>☐ Female ☐ Male ☐ Trans* ☐ Prefer not to disclose</td>
</tr>
<tr>
<td>b)</td>
<td>Age</td>
</tr>
<tr>
<td></td>
<td>☐ 16-24 ☐ 25-34 ☐ 35-44 ☐ 45-54 ☐ 55-64 ☐ 65-74 ☐ 75+</td>
</tr>
<tr>
<td>c)</td>
<td>Do you have a mobile phone?</td>
</tr>
<tr>
<td></td>
<td>☐ no ☐ yes, with: ☐ Internet ☐ Barcode scanner ☐ NFC reader</td>
</tr>
</tbody>
</table>

Survey: Social Object Annotation

Quarter Winter, University of Brighton

- 400 -
### System Usability

<table>
<thead>
<tr>
<th>Statement</th>
<th>Strongly disagree</th>
<th>Strongly agree</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. I think that I would like to use this system frequently</td>
<td></td>
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<tr>
<td>2. I found the system unnecessarily complex</td>
<td></td>
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<tr>
<td>3. I thought the system was easy to use</td>
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<tr>
<td>4. I think that I would need the support of a technical person to be able to use this system</td>
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<td>5. I found the various functions in this system were well integrated</td>
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<tr>
<td>6. I thought there was too much inconsistency in this system</td>
<td></td>
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<td>7. I would imagine that most people would learn to use this system very quickly</td>
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<tr>
<td>10. I needed to learn a lot of things before I could get going with this system</td>
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</table>

### Interview Response Rate Tally

Keep track of the number of people approached, declined etc. Use ✔️ to indicate.

<table>
<thead>
<tr>
<th>Approached by the researcher:</th>
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<tbody>
<tr>
<td></td>
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<tr>
<td>Listened to verbal explanation:</td>
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<td></td>
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<tr>
<td>Read information sheet:</td>
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<td></td>
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<tr>
<td>Signed consent form:</td>
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<td></td>
</tr>
<tr>
<td>Completed interview:</td>
</tr>
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<td></td>
</tr>
<tr>
<td>Offered contact details for follow-up:</td>
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<td></td>
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</table>
## Contact Form

If you'd like to stay in touch / receive results

<table>
<thead>
<tr>
<th>Name</th>
<th>Email</th>
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</table>
Appendix G: Instrument for empirical evaluation 1: Fail Better

Observations coding sheet

<table>
<thead>
<tr>
<th>Date:</th>
<th>Start time:</th>
<th>End time:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Location:</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Part of Group (n)</th>
<th>Look at object</th>
<th>Look at label</th>
<th>Look at SOL</th>
<th>Point others to SOL</th>
<th>Scan QR</th>
<th>Touch NFC</th>
<th>Enter URL</th>
<th>Read comment</th>
<th>Write comment</th>
<th>Other (in ref)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td></td>
<td></td>
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Appendix H: Instrument for empirical evaluation 2: Home\Sick

Evaluation at HOME\SICK: POST-DOMESTIC BLISS

"HOME\SICK: POST-DOMESTIC BLISS ... looks at the meanings of home, from rubbish to robots and microbes to micro-dwellings, asking whether the changing nature of home is for better or worse."

- Four SOLs installed in the gallery space for a duration of 3 weeks
- Each SOL attached to (or next to) one specific exhibit (see candidate exhibits)
- SOLs periodically change their layout in order to evaluate different designs

Data collection

- Technical logs of interactions with SOL and mobile application
  - quantify / qualify visitor interaction with different SOL layouts in order to test design assumptions
  - model typical "user journeys" on SOL
  - quantify preferred PMI methods
  - quantify mobile interaction
  - model typical "user journeys" on mobile
  - assess discoverability and learnability of SOL and mobile interfaces

- Observations in gallery
  - awareness of SOLs
  - engagement / interaction
  - triangulate with technical logs and interviews

- Visitor interviews
  - awareness of SOLs
  - mental models (purpose / interaction)
  - user experience of engagement
  - barriers to engagement
  - attitudes to using mobile in exhibition space
## Setup / Rotor

- Total of 7 design variations to evaluate, all of which need equal exposure:
  - day of week (workday, weekend)
  - time of day
  - exhibit
- SOLs automatically switch UI at certain times (see below)
- Switches are synchronised so that all SOLs show the same UI at any given time. This helps with recognition when visitors move through the gallery and leverages prior learning about interaction

<table>
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<th>Day</th>
<th>LO</th>
<th>Weekday 12:00-16:00</th>
<th>Layout No.</th>
<th>Weekend 12:00-15:00</th>
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Appendix H: Instrument for empirical evaluation 2: Home Sickness

Interview script

1. Hello I'm from the University of Brighton, would you have a few minutes to answer some questions? [follow sampling method]

   → →

2. My name is...

3. I'm working on a research project about commenting technologies in museums and galleries.

4. I'd like to ask you some questions on your experience today at the Science Gallery.

   It will take about 4-5 minutes. Would that be ok?

   → →

5. Do you prefer doing the interview here or would you rather sit down? [if standing]

   There are some chairs over there... [check options before]

6. Before we start, I'd like you to understand what the research is about.

   - Here's an information sheet [info sheet]
   - Please take a minute to read this; I can read it to you if you prefer.
   - If anything is unclear, please ask.

7. Thank you!

   → →

8. OK, let's jump right in...

   ... follow survey instrument for with / without interaction....

9. Thank you for your time! [put away notes]

10. Do you have any other comments or questions?

11. If you'd like to stay in touch or get notified about the results of the research please leave your name and email address here. This is not linked to your interview data, which will remains anonymous!

12. Thanks again! [participant leaves]

   → →

13. Go over notes immediately, clarify, amend, ensure readability

14. Update response rate tally
Appendix H: Instrument for empirical evaluation 2: Home\Sick

<table>
<thead>
<tr>
<th>People who did NOT interact with SOLs</th>
<th>Exhibit</th>
<th>Layout</th>
</tr>
</thead>
<tbody>
<tr>
<td>1) Did you notice the display next to &lt;exhibit&gt;?</td>
<td>☐ yes</td>
<td>☐ no</td>
</tr>
<tr>
<td>2) What would you think it is for?</td>
<td>☐ don’t know</td>
<td>☐ display comments</td>
</tr>
<tr>
<td></td>
<td>☐ read comments</td>
<td>☐ write comments</td>
</tr>
<tr>
<td>3) Do you think it’s interactive?</td>
<td>☐ yes</td>
<td>☐ no</td>
</tr>
<tr>
<td>4) How would you use it?</td>
<td>☐ don’t know</td>
<td>☐ use mobile phone</td>
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<tr>
<td></td>
<td>☐ enter code</td>
<td>☐ scan QR code</td>
</tr>
<tr>
<td>5) What kind of content would you expect when scanning it?</td>
<td>☐ information</td>
<td>☐ website</td>
</tr>
<tr>
<td>6) Would you expect that you can put in your own comments?</td>
<td>☐ yes</td>
<td>☐ no</td>
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<tr>
<td>7) What would make you try it out?</td>
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<td>8) Do you think it’s OK for people to use their mobile in a gallery space, for example to take a picture or look up information?</td>
<td>☐ yes</td>
<td>☐ no</td>
</tr>
<tr>
<td>9) Does using your mobile in these ways spoil your gallery experience?</td>
<td>☐ yes</td>
<td>☐ no</td>
</tr>
<tr>
<td>10) Do you think mobile phone use is welcome in this gallery?</td>
<td>☐ yes</td>
<td>☐ no</td>
</tr>
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</table>

Demographics

“Maybe you’d like to fill this in yourself…”

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<thead>
<tr>
<th>a) Gender</th>
<th>☐ Female</th>
<th>☐ Male</th>
<th>☐ Trans*</th>
<th>☐ Prefer not to disclose</th>
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<tbody>
<tr>
<td>b) Age</td>
<td>☐ 18-24</td>
<td>☐ 25-34</td>
<td>☐ 35-44</td>
<td>☐ 45-54</td>
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<tr>
<td>c) Do you have a mobile phone with touch screen and internet?</td>
<td>☐ yes</td>
<td>☐ no</td>
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<td>d) Do you use Twitter on your mobile?</td>
<td>☐ yes</td>
<td>☐ no</td>
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<tr>
<td>e) Did you ever scan a QR code?</td>
<td>☐ yes</td>
<td>☐ no</td>
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<tr>
<td>f) Did you ever scan an NFC tag?</td>
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<td>☐ no</td>
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<tr>
<td>People who DID interact with SOLs</td>
<td>Exhibit</td>
<td>Layout</td>
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<tr>
<td>1) When you first noticed the display next to exhibit, what did you think it was for?</td>
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<tr>
<td>☐ don't know ☐ display comments ☐ read comments ☐ write comments</td>
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<tr>
<td>2) Was it clear how it works?</td>
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<td>☐ yes ☐ no ☐ not sure</td>
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<td>3) What kind of content did you expect when you first used it?</td>
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<td>☐ information ☐ website ☐ comments ☐ not sure</td>
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<td>4) Was it clear that you can put in your own comments?</td>
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<td>☐ yes ☐ no</td>
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<td>5) Was it worth touching/scanning* it?</td>
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<td>☐ yes ☐ no</td>
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<td>6) Would you touch/scan* it again (other exhibit)?</td>
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<td>☐ yes ☐ prob. yes ☐ maybe ☐ prob. no ☐ no</td>
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<td>7) Did you add a comment?</td>
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<td>☐ yes ☐ no</td>
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<tr>
<td>7Y) Did it behave as you expected?</td>
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<tr>
<td>☐ yes ☐ no</td>
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<tr>
<td>7Y) What would make you add a comment?</td>
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</table>

**Demographics**

“Maybe you’d like to fill this in yourself…”

a) Gender
- ☐ Female
- ☐ Male
- ☐ Trans*
- ☐ Prefer not to disclose

b) Age
- ☐ 18-24
- ☐ 25-34
- ☐ 35-44
- ☐ 45-54
- ☐ 55-64
- ☐ 65-74
- ☐ 75+

c) Do you have a mobile phone with touch screen and internet? | ☐ yes | ☐ no | ~
d) Do you use Twitter on your mobile? | ☐ yes | ☐ no | ~
e) Did you ever scan a QR code? | ☐ yes | ☐ no | ~
f) Did you ever scan an NFC tag? | ☐ yes | ☐ no | ~
Participant Information Sheet

Evaluation Study: Social Object Labels

Researcher: Marcus Winter

Project Title: Social Object Labels: Developing Design Principles

Invitation

You are being invited to take part in a research study. Please read the following information before you decide to take part. Talk to others about the study if you wish and ask the researcher if there is anything unclear or if you would like more information.

What is the purpose of the interview?

The research develops new technologies for commenting and feedback in museums and galleries. To inform the design process, we need to know what visitors think about our current prototype.

Why have I been chosen?

You are being asked to take part in the research because you are visiting the Science Gallery Dublin and might have noticed or interacted with our current prototype.

Do I have to take part?

You do not have to take part and you are free to withdraw at any time and without giving a reason. If you do take part, you will be asked to sign a consent form.

What will happen to me if I take part?

You will be asked some questions about your experience in the gallery and your thoughts on our current prototype. The interview will take about 5 minutes.

What are the possible disadvantages and risks of taking part?

The interview is anonymous and does not ask any personal questions.

What are the possible benefits of taking part?

You might find the experience interesting and, if you wish, will be notified about results of the study.

What will happen if I don’t want to carry on with the study?

You are free to withdraw from the interview at any time without giving any reason.

Will my taking part in this study be kept confidential?

All information collected in this interview will be kept strictly confidential. The data will be stored in a secure area and not be made available outside the context of this research. It will be held as long as necessary for the research and destroyed thereafter.

What will happen to the results of the research study?

Results of the research may be presented at academic conferences and in academic journals. In some cases the researcher may wish to include verbatim quotes in reports or publications. If this is the case, quotes will be anonymous and you will not be able to be identified.

What if there is a problem?

If you have any problems or complaints regarding the research please discuss them in first place with the researcher. If you are not satisfied that your concerns are dealt with appropriately, please contact the Doctoral College Centre SE at the University of Brighton (contact details overleaf).
Contact Details

Marcus Winter (Researcher)
602 Watts Building, Moulsecoomb, Brighton BN2 4GJ
telephone: +44 (0)1273 642476
e-mail: marcus.winter@brighton.ac.uk

Doctoral College Centre for Science and Engineering
211 Mithras House, Moulsecoomb, Brighton BN2 4AT
telephone: +44 (0)1273 641104 or 641105 or 641108
e-mail: s.jenkins@brighton.ac.uk
Consent Form

Evaluation Study: Social Object Labels

Researcher: Marcus Winter
Project Title: Social Object Labels: Developing Design Principles

Consent

1. I agree to be involved in this research which investigates design aspects of Social Object Labels. I give my permission for the researcher to use excerpts from the interview for his research.

2. The researcher has explained the research to my satisfaction and I have read the information sheet. I understand the principles and processes of the study.

3. I am aware that I will be asked to take part in an interview discussing my experience in the gallery with regard to Social Object Labels.

4. I understand that the interview is anonymous and no personal information will be collected.

5. I understand that my participation is voluntary and that I am free to withdraw at any time without giving any reason.

6. I understand that collected data will be stored in a secure area and held only as long as necessary for the research. The data will not be made available outside the context of this research.

7. I understand that collected data will be used as part of a research project and that results of the research might be presented at academic conferences and in academic journals.

8. I agree to take part in this study.

__________________________________________________________________________
Name of Participant Date Signature

__________________________________________________________________________
Name of Person taking consent Date Signature
(if different from researcher)

Marcus Winter
Researcher Date Signature

- 413 -
## Contact Form

If you'd like to stay in touch / receive results

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<thead>
<tr>
<th>Name</th>
<th>Email</th>
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### Interview Response Rate Tally

Keep track of the number of people approached, declined etc. Use "|||" |||

<table>
<thead>
<tr>
<th>Action</th>
<th>Count</th>
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<tbody>
<tr>
<td>Approached by the researcher</td>
<td></td>
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<tr>
<td>Listened to verbal explanation</td>
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<tr>
<td>Read information sheet</td>
<td></td>
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<tr>
<td>Completed interview</td>
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<tr>
<td>Offered contact details for follow-up</td>
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</tbody>
</table>