Assessing representative task design in cricket batting: Comparing an in-situ and laboratory-based task.

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Assessing representative task design in cricket batting: Comparing an in-situ and laboratory-based task.

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Abstract

It has been argued that representative tasks are needed to understand the processes by which experts overcome their less skilled counterparts. Little is known, however, about the essential characteristics of these tasks. In this study we identified the degree to which a laboratory-based task of decision making in cricket batting represented *in-situ* performance. The *in-situ* task required skilled batters to play against a bowler across a range of delivery lengths. Skilled batsmen produced a transitional pattern of foot movements with front foot responses being dominant for balls landing 0 – 6m from the wicket and back foot responses for balls landing 8 – 14m from the wicket. In the laboratory-based task, the same batsmen viewed video footage of the same bowlers. Again, skilled batsmen responded with similar patterns of foot movement transitions. Novice batsmen produced a generic forward movement in response to all deliveries. We conclude that for decision making about delivery length, the laboratory-based task has a high degree of fidelity and reliability. The implications of these results are discussed in relation to the importance of establishing the necessary degree of fidelity of representative task designs in order to study perception and action more accurately.

*Key Words:* Behavioral Dynamics, Decision Making, Perception, Perceptuo-motor Threshold, Information-movement Scaling, PROBIT
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There has been much debate about methodological approaches used to study perception and action in sport (Araujo & Davids, 2009). When used in a laboratory setting, the occlusion paradigm can offer experimental rigor and a high degree of control (Davids, 2008), as well as administrative convenience (Mann, Abernethy, & Farrow, 2010). However, there has been a shift in research design towards a more ecological approach, which offers potentially greater predictive value when generalizing results to the intended environment.

Ericsson and Smith (1991) proposed the first descriptive and inductive framework for the study of expertise in sport, the expert performance approach. This approach shares common underpinnings with the work of Starkes, Edwards, Dissanayake, and Dunn (1995) who were the first to study perceptual skills of volleyball players in a game setting. This study was made possible through technological advancement, allowing the researchers to temporally occlude vision using liquid crystal occlusion glasses. This increased external validity by providing participants the opportunity to track real ball flight characteristics as opposed to two dimensional representations.

A decade later, some argued that concerns regarding assessment of decision making under game-like conditions had still not been fully addressed (e.g., Mann, Williams, Ward & Janelle, 2007; Williams & Ericsson, 2005). van der Kamp, Rivas, van Doorn and Savelsbergh (2008) stated that the failure to preserve the functional coupling between perception and action in the design of experimental tasks has limited the expert performance approach (see also Araujo, Davids & Hristovski, 2006) and that current understanding of perceptual motor skill might have been compromised through experimental designs that are not representative of performance.
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contexts (Pinder, Davids, Renshaw & Araujo, 2011). These discussions, concerning valid task designs for the study of expert performance, have led to the question, what type of ‘laboratory’ task is representative enough?

Brunswik (1956) first defined representative design as the study of psychological processes at the level of organism-environment relations. Understanding the interaction between key organism, task, and environmental constraints for the emergence of adaptive behavior provides a powerful theoretical framework for designing representative tasks; regardless of whether they are performed in the laboratory or the field setting. There have been some recent empirical attempts to bring about such task representation across a range of sports including; soccer (Dicks, Button, & Davids, 2010), rugby (Correia, Araujo, Cummins, & Craig, 2010), baseball (Ranganathan & Carlton, 2007) and tennis (Williams, Ward, Smeeton, & Allen, 2004).

Brunswik’s original concepts concerning task representativeness have more recently been re-interpreted in the context of sport science (Pinder, Davids & Renshaw, 2011). They proposed the notion of representative learning design as an important methodological feature for the study of how processes of perception, cognition, decision-making, and action underpin intentional movement behaviors in dynamic sporting environments In order to achieve representative learning design, Pinder, et al. (2011) suggest that practitioners should, a) design dynamic interventions that consider interacting constraints on movement behaviors, b) use tasks that allow for adequate sampling of informational variables from the specific performance environments to allowing detection of affordances for action, and c) ensure coupling between perception and action is maintained to support functionality and fidelity of performance.
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In order to evaluate the level of functionality of performance, Stoffregen, Bardy, Smart, and Pagulayan (2003) proposed the concept of action fidelity, which is the degree of transfer of performance from the simulator to the simulated system. Pinder, et al. (2011) suggest that when developing representative laboratory tasks, practitioners should examine the degree of fidelity between actions that emerge from the individual’s interactions with the experimental task and the performance setting. However, the task of assessing adaptive behavior in a performance context is difficult, especially in fast interceptive actions that require sub-second, externally-paced responses to environmental stimuli (Muller, Abernethy, & Farrow, 2006). Araujo, et al. (2006) state that decision-making is a complex temporally extended process, which is not best understood if an individual is characterized as making decisions prior to their behavioral expression. Because of the close link between decision-making and their behavioral expression, they argue that analysis of adaptive behaviors is a way of identifying decision-making in these environments.

Previous laboratory-based studies into cricket batting have shown that skilled batsmen have a superior ability to extract advanced cues from a bowler’s movements (Renshaw & Fairweather 2000, Müller et al., 2006, & Weissensteiner, Abernethy, Farrow, & Müller, 2008). They do this by using more efficient visual search strategies, compared to novices, in order to make informed decisions (McRobert, Williams, Ward, & Eccles, 2009). Although these studies provide insight into how highly skilled participants respond compared with less skilled participants, they may not be representative of the constraints found in situ. Specifically, in these studies there may be a low degree of perception-action coupling that is a function of the controls adhered to in the laboratory setting, such as video footage, instead of a live
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In answer to some of the issues raised with laboratory tasks, Mann, Abernethy, and Farrow (2010) studied the effect of differing levels of movement coupling by comparing four response methods (verbal, foot movement, shadow batting, and total batting) between skilled and novice cricket batsmen in situ. Skilled, but not novice, anticipation was found to increase with response modes that more closely represented the natural movement. Mann, et al. (2010) suggested that allowing an athlete to engage in the opportunity to make bat-ball contact increases the ability to differentiate between skilled and novice performers. This finding endorses Pinder et al.’s (2011) framework of representative learning design, highlighting the importance of using experimental procedures that reflect the task demands of the natural performance environment, maintaining coupling to support functionality of natural movements.

Junior cricket batsmen were also studied in situ across pre-determined delivery lengths (Pinder et al., 2012). Using the language of ecological dynamics, the authors aimed to examine a point at which the movement system changed from one dominant movement solution to a second movement solution, in order to satisfy task goals. At a pre-determined delivery length of 7.5m, batters were forced into a region of performance where rich and varied patterns of functional movement behaviors emerged. This study highlights the importance of studying a movement system across a range of performance variables, allowing adequate sampling of information variables in order to understand how (and when) adaptive behaviors emerge. Nonetheless, the use of pre-determined, anecdotally prescribed delivery lengths and unrepresentative delivery speeds raises questions as to whether or not the participant’s responses can be considered as representative in a decision making context.
In this study, we aim to identify if a laboratory-based task is able to sustain the emergence of adaptive behavior by simulating (representing) interactions between the organism, task, and the environment compared to *in situ*. In order to address the aforementioned methodological limitations that have been cited in the literature, we identified the adaptive behaviors present in cricket batting that emerge across a range of delivery lengths *in situ*. This was to be used as a benchmark of the representative task. We expected skillful emergent behavior to be represented by a dominant front foot movement response to deliveries that pitched closer to the batsman, transitioning into an area of high foot movement variability (Pinder *et al*., 2012), followed by a dominant back foot movement response to deliveries that pitched further away from the batsman. Second, we assessed the degree of fidelity of adaptive behavior in our laboratory-based task by comparing it with those found *in situ*. If the pattern of adaptive behavior observed in the *in-situ* task was also found in the laboratory task, then we would assume that the necessary links between perception and action were present in the laboratory task (Mann *et al*., 2010; Pinder *et al*., 2011). We assessed the test versus re-test reliability of skilled batsmen’s adaptive behavior under laboratory conditions. To assess the construct validity of the task, skilled batsmen were compared to novices on the laboratory-based batting task (e.g. Ericsson & Smith, 1991). If skill-based differences were found then the task was considered to be representative of skillful batting in response to varied delivery lengths.

**Method**

**Participants**

Thirteen skilled right-handed male cricket batters (age: 23.2 ± 3.8 years), with 11.5 ± 2.33 years playing experience, and twelve novice right-handed male
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participants (age: 25.3 ± 3.2 years) were recruited for the study. Skilled participants were included in the study if they had at least eight years of formal playing experience and were playing at a regional, first division level for the past two years (in the UK). Novice participants were required to have no competitive cricketing experience. Two right-arm bowlers (age: 21.6 ± 1.7 years) with 8.66 ± 1.52 years playing experience with similar conventional bowling actions and physical attributes (average height of release: 2.09 ± 0.06 m; average bowling speed: 32.63 ± 0.78 m.s$^{-1}$) were also recruited. Participants provided informed consent prior to testing and ethical clearance was received from the local institutional ethics’ committee.

**Design and Procedure**

Batters’ foot movements were analyzed in three separate conditions to evaluate fidelity from *in-situ* to the laboratory. An *in-situ* movement condition was completed first to allow the experimenters to model adaptive behaviors across a range of delivery lengths (Araujo *et al.*, 2006). Second, the experimenters recorded video footage of the same two bowlers from the *in-situ* environment to create two laboratory-based conditions.

After a familiarization protocol, the skilled participants completed the two separate, counterbalanced laboratory conditions. The first laboratory-based condition was used to evaluate fidelity between laboratory and *in-situ* emergent actions. The second condition was used to evaluate the within-day reliability of the laboratory-based task. It was decided that within-day variability analysis was appropriate for our study, because we wished to assess performance without the confound of further cricket training. Novice participants completed only one laboratory condition to assess if laboratory task performance was different between skill levels of performers (i.e., a construct validity test). For the skilled participants, 72 *in-situ* trials and 100
laboratory trials per participant were analyzed for fidelity of in-situ versus laboratory performance and 100 trials per participant were analyzed for test versus re-test reliability. For the novice participants (in comparison to the skilled), 50 trials per participant were analyzed for differences.

**Skilled In-situ Batting**

An indoor artificial cricket net was set up according to the International Cricket Council (ICC) pitch regulations. Prior to analysis, a sport specific warm-up and a 12-ball (6 deliveries per bowler) familiarization protocol were carried out. None of the 13 batsmen had previously faced any of the two bowlers, but had faced bowlers of a similar speed and ability in training. Batsmen were instructed to play naturally whilst keeping (i.e., protecting) their wicket; they were set a standard medium – fast pace field setting scenario in attempt to replicate on-field demands. The bowlers were instructed to bowl a variety of delivery lengths. Each analysis consisted of 12 blocks of 6 trials, alternating blocks between bowlers (72 deliveries total, 36 deliveries per bowler). Two high definition (1080p) video cameras (Canon LEGRIA HF R46, Tokyo, Japan, & Sony Handycam HDR-TD10E, Tokyo, Japan) were positioned parallel to the pitch (see Figure 1) to record the batsman’s movement kinematics in the frontal plane. Delivery length was measured as the distance from the point of ball bounce to the base of the stumps at the batsman’s end of the wicket. Calibration was attained using horizontal and vertical references of known distance.

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Insert figure 1 about here

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**Laboratory Batting**
A ceiling mounted projector was used to display the experimental footage onto a projection screen (L = 1.35m, W = 1.35m, see Figure 2). A batting crease was set up according to ICC regulations and positioned such that a life size image of the bowler was seen. Participants were instructed to respond to the video with natural batting strokes aimed at making bat-ball contact whilst keeping their wicket. An initial familiarization protocol was used to allow participants to adapt to the laboratory settings, after which the participants viewed two 50-delivery test tapes. Participants were given the same playing instructions as given in situ. Participants’ movement kinematics were recorded using the same procedure as in situ.

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Insert figure 2 about here

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**Video Production and Test Construction**

The same bowlers from the in-situ analysis were instructed to bowl from the popping crease (located 18.90m from the bowling crease at the batsman’s end) towards the stumps and land the ball at five ranges of delivery lengths from the batsman’s stumps, identified by the in-situ analysis. These consisted of a) “Very Full” (0-3m), b) “Full” (3-5m), c) “Neutral” (5-7m), d) “Short” (7-10m), and e) “Very Short” (10-14m), with 12 deliveries for each delivery length. The representative video footage of the bowlers was filmed (Sony Handycam HDR-TD10E, Tokyo, Japan) from the batter’s preparatory position on the batting crease and at a height of 1.76m. This camera was positioned, zoomed, and focused to replicate a batsman’s natural viewing perspective. Another high definition video camera (Canon LEGERIA HF R46, Tokyo, Japan) was positioned in the same location as the in-situ set up to record the ball flight characteristics of the bowlers’ deliveries. Delivery length was measured...
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from the point of ball bounce to the base of the stumps at the batter’s end. The footage was then edited into 50 single deliveries (5 deliveries x 5 delivery lengths x 2 bowlers), starting from the initiation of the bowler’s run up, until the point at which they had finished their delivery follow through and the ball was no longer visible on the screen. Single deliveries were used to construct the experimental test tape in randomized delivery lengths. A re-test experimental tape was constructed from the same deliveries as the test tape, but was presented in a different order, again randomized for delivery length. The test tapes contained a balanced number of deliveries, consisting of ten deliveries, five from each bowler, in each length category.

Data Collection

A high definition video camera was used to record participant’s movements in situ and in the laboratory. This footage was then calibrated for distance using Silicon Coach Pro 7 software (Dunedin, New Zealand). Once calibrated, each front and back foot movement distance was measured. Each foot was fitted with a marker at the head of the talus. This anatomical marker was used to measure absolute foot movement. Each measure was taken from the last frame before the foot had lifted off from the ground, until the first frame that the foot had been fully placed onto the ground. Inter- and intra-rater reliability were assessed on the same 100 trials. Strong correlations were found for both intra- ($r = .92$) and inter-rater ($r = .89$) reliability.

Measures

Foot movement response proportion. Foot movement response proportions were calculated for front foot and back foot separately as well as forwards and backwards movements. For each foot and foot movement direction, the number of movements made within that 1m-delivery length region was calculated as a
percentage of the total number of deliveries landing in that 1m region. This allowed the experimenters to identify typical responses across the fourteen 1m regions.

**Foot movement magnitude.** Foot movement magnitude was defined as the forwards-backwards direction (+/-) and distance (metres) that each foot moved during shot execution.

**PROBIT foot movement transition.** PROBIT analysis (Finney, 1952) was used to model the probability that a foot movement, forwards or backwards, would be observed for a given delivery length. We wished to identify the delivery lengths at which participants changed the direction of their movement (i.e., foot movement responses), with the following probabilities; 95%, 50% and 5%. These would reflect ‘dominant’, ‘neutral’, and ‘non-dominant’ movements respectively.

**Data analysis**

The *in-situ* and laboratory performance data were grouped by 5 delivery lengths (0-3m, 3-5m, 5-7m, 7-10m, 10-14m). Intra-class correlation coefficient analyses were used to measure the degree of agreement between *in-situ* and laboratory foot movement response proportions and magnitudes across delivery lengths. Furthermore, two-way, within-subject ANOVAs with Condition (*in-situ*, laboratory) and Delivery lengths (0-3m, 3-5m, 5-7m, 7-10m, 10-14m) were used to analyze participants’ foot movement response proportions and magnitudes separately. To examine differences between skill groups, data were grouped into 14, one metre regions. Two-way, mixed design ANOVAs with Skill (skilled, novice) and Delivery length (0-14m) were used to analyze participants’ foot movement response proportions and magnitudes separately. The assumptions of ANOVA were tested for and no violations were found. Significant effects of ANOVA were followed up using
Bonferroni corrected independent and dependent samples t-tests. Effect sizes were reported as Partial eta-squared ($\eta_p^2$) values.

PROBIT analysis was used to transform foot movement response proportions across delivery lengths into a response probability curve. This analysis involves the application of an inverse cumulative distribution function that is applied to binary response variables across a continuous variable. The continuous variable is categorized across its range and a probability of a response occurring is given across the continuous variable based on the number of responses/category of the continuous variable and the total number of events a response can be given. In accordance, metre-region categories were created for delivery lengths 0-14m. A binary response was recorded when the dominant foot movement was made forward for front foot movements and backwards for back foot movements. These variables were analyzed in order to identify the delivery length that resulted in 95th, 50th, and 5th percentile probability of foot movements being made. To aid visualization of the magnitude of the foot movements, the binary response variable (forward/backward) has been converted back to the absolute foot movement distance (m) and has been plotted alongside the response probability curve (Figures 4 and 5).

**Results**

**In-Situ versus Laboratory**

**Front foot response proportions.** A significant main effect was shown for condition, $F(1,12) = 5.66, p<0.05, \eta_p^2 = .32$. A larger percentage of front foot movements were observed in the laboratory compared with the in-situ task. A significant main effect was also found for delivery length, $F(4,48) = 142.75, p<0.05, \eta_p^2 = .92$, with significant differences ($ps <0.05$) between all distances except 0-3m and 3-5m (as shown in Figure 3). There was also a significant Condition x Length
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interaction, $F(4,48) = 3.85, p<0.05, \eta_p^2 = .64$ (see Figure 3). Front foot response proportions under in-situ and laboratory protocols significantly differed between the 0-3m and 7-10m delivery lengths only.

**Back foot response proportions.** No significant main effect for condition was shown, $F(1,12) = 0.72, p>0.05, \eta_p^2 = .057$. There was, however, a significant main effect of length, $F(4,48) = 108.79, p<0.05, \eta_p^2 = .90$. As with the front foot, all lengths were significantly different, except between the 0-3m and 3-5m distances (see Figure 3). A significant Condition x Length interaction effect was shown, $F(4,48) = 5.38 p<0.05, \eta_p^2 = .31$, with the significant differences across conditions being at the 3-5 and the 7-10m delivery length conditions. A larger percentage of back foot movements were observed in the laboratory at the 3-5m delivery length, whilst a smaller percentage of movements were observed at the 7-10m delivery length compared with in-situ (see Figure 3).

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Insert figure 3 about here

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**Front foot movement magnitudes.** A significant main effect for the size of front foot movements was shown for condition, $F(1,12) = 7.24, p<0.05, \eta_p^2 = .38$, with larger magnitudes of front foot movements being observed in the laboratory. A significant main effect of length, $F(4,48) = 169.33, p<0.05, \eta_p^2 = .93$, was due to significant differences between 3-5m ($M_{diff} = 0.36m, SD = 0.02$) and 5-7m ($M_{diff} = 0.15m, SD = 0.03$), between 5-7m and 7-10m ($M_{diff} = -0.08, SD = 0.04$) and between 7-10m and 10-14m ($M_{diff} = -0.42m, SD = 0.46$). A significant Condition x Length interaction $F(4,48) = 21.99 p<0.05, \eta_p^2 = .65$, resulted from differences between lab and in-situ in the 7-10m delivery length only.
**Back foot movement magnitudes.** No significant main effect for the size of back foot movements was shown for Condition (F<1). However, there was a significant main effect of Length, \( F(4,48) = 88.77, p<0.05, \eta_p^2 = .88 \), with significant differences between 3-5m (\( M_{diff} = 0.08m, SD = 0.00 \)) and 5-7m (\( M_{diff} = -0.02m, SD = -0.01 \)), and between 5-7m and 7-10m (\( M_{diff} = -0.22m, SD = -0.02 \)) and between 7-10m and 10-14m (\( M_{diff} = -0.31m, SD = -0.03 \)). A significant Condition x Length interaction, \( F(4.48) = 4.47 p<0.05, \eta_p^2 = .272 \), was due to significant differences between the conditions at the 3-5m and the 7-10m delivery lengths, with larger magnitudes of back foot movements in the laboratory at the 3-5m length and smaller magnitudes of movements in the laboratory being observed at the 7-10m length.

**Foot movement correlations.** A strong level of agreement was identified for front foot, \( r (12) = .95 p < .05 \) and back foot, \( r (12) = .88 p < .05 \), movement magnitudes between in-situ and laboratory protocols. Therefore, changes in foot movements in situ were strongly associated with changes in foot movements in the laboratory conditions.

**PROBIT foot movement transitions.** In general, the probabilities of front foot movements were reflective of the in-situ and laboratory tasks. Data from the PROBIT analysis of the front foot response proportions indicated that the 50% probability threshold for a forward movement being made in situ was at the 7m delivery length region whereas this was at the 8m delivery length region in the laboratory task (see Figure 4). The 95% and 5% probability thresholds were at the 1.5m and 11.5m delivery lengths for the in-situ task and 2.5m and 14m for the laboratory tasks respectively. PROBIT of the back foot response proportions revealed that the 50% probability threshold was reached at 5.5m for the in-situ task and 6.5m for the laboratory tasks (see Figure 5). The 95% and 5% probability was reached at the
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11.5m and 0m respectively for the *in-situ* task and the 95% probability was reached at 14m for the laboratory task, but the 5% probability was not reached.

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Figure 4 & 5 about here
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**Reliability.**

*Foot movement correlation.* A strong level of agreement was identified in front foot, \( r(12) = .99 \ p < .05 \) and back foot, \( r(12) = .99 \ p < .05 \), movement magnitudes between test versus re-test protocols (see Figure 6).

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Figure 6 about here
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**Front foot movement.** No significant main effect was found for test type, \( F<1 \). Although there was a significant effect of length, \( F(4,48) = 76.09, \ p<0.05, \ \eta^2_p = .76 \), there was no Test type x Length interaction, \( F<1 \).

**Back foot movement.** Again there was no significant effect of test type, \( F<1 \) or a Test type x Length interaction (\( F<1 \)). A significant main effect of length was shown, \( F(4,48) = 50.71, \ p<0.05, \ \eta^2_p = .68 \).

**Between- and Within-participant Variability:**

In order to show the pattern of variability in front foot movement magnitudes under laboratory and *in-situ* across delivery lengths and between individuals, between- and within-participant variability values have been displayed in Table 1. Overall, between-participant variability was relatively low, although there were some exceptions (e.g., participant 2, 7 (in situ) and 8 (Laboratory) showed generally higher overall SDs). Between-participant variability as a function of delivery length was
higher and may be reflective of forward-backward transition points being located at different delivery lengths across for some participants. Variability was generally lower in the laboratory task than the in situ task and it increased at delivery lengths landing near 7-8m from the stumps.

Insert Table 1. about here

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**Construct Validity comparing Novice and Skilled participants:**

**Front foot response proportion.** There was a significant effect of skill, $F(1,23) = 14.14, p<0.05, \eta_p^2 = .38$ and length, $F(1,23) = 17.50, p<0.05, \eta_p^2 = .43$. A significant Skill x Length interaction effect, $F(1,23) = 19.73 p<0.05, \eta_p^2 = .46$, showed significant differences between skill groups at 0-1m, 7-8m, 8-9m, 9-10m, 10-11m, 11-12m, 12-13m and 13-14m delivery length conditions. Novices had higher percentages of front foot movements than skilled performers across these lengths.

**Back foot response proportion.** Again a significant skill effect, $F(1,23) = 20.51, p<0.05, \eta_p^2 = .47$ and length effect, $F(13,299) = 19.18, p<0.05, \eta_p^2 = .45$, were shown. A Skill x Length interaction, $F(13,299) = 19.74 p<0.05, \eta_p^2 = .46$, was due to significant differences between groups at 6-7m, 7-8m, 8-9m, 9-10m, 10-11m, 11-12m, 12-13m and the 13-14m delivery length conditions. As would be expected based on the front foot differences, skilled performers had higher percentages of back foot movement proportions than novices at these lengths.

**Front foot movement magnitudes.** Again, there were skill, $F(1,23) = 6.78, p<0.05, \eta_p^2 = .35$ and length, $F(13,299) = 27.14, p<0.05, \eta_p^2 = .54$ effects (see Figure 7). There was also a significant Skill x Length interaction, $F(13,299) = 27.46 p<0.05, \eta_p^2 = .54$, with significant differences between the groups at 6-7m, 7-8m, 8-9m, 9-
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10m, 10-11m, 11-12m, 12-13m and 13-14m delivery length conditions. Novices had larger front foot movement magnitudes than the skilled performers.

**Back foot movement magnitudes.** There was a skill, $F(1,23) = 14.29$, $p<0.05$, $\eta_p^2 = .38$, length, $F(13,299) = 16.40$, $p<0.05$, $\eta_p^2 = .42$, and a Skill x Length interaction, $F(13,299) = 15.72$, $p<0.05$, $\eta_p^2 = .41$. The latter effect was due to significant differences between the groups at 6-7m, 7-8m, 8-9m, 9-10m, 10-11m, 11-12m, 12-13m and the 13-14m delivery length conditions (see Figure 7). Skilled performers had larger back foot movement magnitudes compared with novices.

Discussion

The aim of this study was to examine an emergent behavior from cricket batting *in situ* to evaluate the representative design of a laboratory-based cricket batting task. Skilled batsmen’s foot movements were recorded as an indicator of their decision-making behaviour about delivery length. By comparing the pattern of foot movement behaviour across delivery lengths the degree of fidelity between *in-situ* and laboratory task was evaluated. PROBIT was used to model these data.

*In-situ*, there was a high probability of a forwards front foot movement to deliveries that landed 0-7m from the base of the batters’ stumps. At 7-8 m, no dominant foot movement response was evident. A low probability of a forwards front foot response was shown for delivery ranges between 8-14m from the stumps. As would be expected, this pattern was reversed in the back foot movements *in situ*. These findings support the notion of a meta-stable region of foot movements (Pinder *et al.*, 2012). Additionally, our findings broaden empirical research by modeling
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cricket batsmen’s decision making behaviours (Araujo et al., 2006), thus allowing us to predict the likelihood of behaviours being observed across a range of delivery lengths, and locate the presence of an unstable region of performance.

In order to establish the level of representative design of a laboratory task, we compared the adaptive behaviors of laboratory and in-situ movements. We expected that a high degree of fidelity would be found if the pattern of foot movements identified in-situ were consistent with that of the representative laboratory task. Our data show significant intra-class correlations between in-situ and laboratory for front and back foot movement magnitudes. Also, similar PROBIT foot movement models emerged for both these conditions, indicating that a general pattern was maintained between these conditions. However, PROBIT analyses showed the 50% probability reached in-situ was 1m different in delivery length than the laboratory-based task. ANOVA data also revealed significant differences between in-situ and laboratory conditions at the 0-3m and 7-10m regions for both front foot and back foot movement response proportions between in-situ and laboratory conditions. Specifically, we observed less forward movements in response to deliveries that landed 0-3m away from the batsman in-situ, compared to laboratory.

Collectively, these findings suggest that batsmen are subjected to some degree of information degeneracy in the laboratory task (Davids et al., 2008). Whilst it is difficult to be certain why this was the case, we speculate on two possibilities. Because the similar sigmoid curve patterns of responses were observed, the same informational variables may have been used across in-situ and laboratory task conditions. However, because there was a translational shift in the 50% probability, a mis-calibration of the informational variables could have occurred. We accept that this may result from the misalignment of the visual stimulus when presented in the
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lab. task. To some degree, there was also a stretching and squashing of the sigmoid curve in the laboratory task condition, showing that response probabilities were not as high (or low) for the lab. task and as such less consistent. Again, this suggests that batsmen may not have been able to as easily attend to or glean the important informational variables present in in-situ batting, potentially as a function of degraded depth cues present in the 2D stimulus used in the lab. However, the presence of the same general pattern of response suggests that informational variables required for the purpose of moving forwards and backwards to the delivery were present or, at least, that other informational variables co-varied in a similar way to those variables found *in situ*.

In response to our earlier question, “what is representative enough?”, one should note that this general pattern of movement may or may not be considered representative when evaluating the naturally occurring cricket batting performance (i.e., in a match-like situation). Accordingly, the tests examined in this paper can be considered to be representative for investigating decision-making behaviour about length perception (*Araujo et al.*, 2006). Therefore, we suggest that for a task to be representative it does not necessitate replication of the entire naturally occurring phenomena *in situ* (in this case cricket batting behaviour). In addition, researchers should substantiate claims of task representativeness (or lack of) with data. Furthermore, this may require the identification of complex trends in data. For example, here, more importance is placed on the pattern of movements across the transition point rather than there being a specific transition point when evaluating differences between in situ and laboratory conditions.

Significant differences between the conditions occur most frequently at the 7-10m length region. From a dynamical systems theory (DST) perspective, this length
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corresponds to a meta-stable region of performance (Pinder et al., 2012). According to DST, increased variability is indicative of movements around bifurcation point, where no stable attractor is present to ‘hold’ a movement pattern for example. Therefore, any differences in the transition point around this region of variability are not considered as important as the overall pattern of the movement across this transition point. For instance, different transition points will be found for different playing surfaces and different bowlers. However, the theoretical notion of a bifurcation point around movement transitions raises some interesting questions about how this point might change as a consequence of perceptual motor skill learning. For example, would the size of the region of instability be reduced as a perceptual motor skill improves? Is this a universal feature of perceptual motor skill? These questions could be addressed in future research using the PROBIT analysis in a longitudinal study of skill learning. Potentially this might provide an objective metric by which skilled performance could be compared between and across task domains.

We also aimed to identify the reliability of the laboratory-based task, and examine if the task was able to discriminate between skilled and novice batsmen. Between the test and re-test, strong, positive correlations were shown and no significant differences. These results highlight that participants responded in a consistent way to the video-based stimuli across a range of delivery lengths in the laboratory task. Significant differences between skilled versus novice front and back foot movements across 7-14m delivery lengths were observed. Therefore, the laboratory task could discriminate between skilled and novice actions across a range of delivery lengths. Participants in the skilled group seemed to be able to extract task-specific information for their foot movements, with a systematic change in
movement direction as delivery length changed. Novices however, did not change their movements in response to the changes in delivery length. There was a large forward bias in the novices’ movements to delivery lengths. The observed forward foot bias response may be due to the fact novice participants have no task-specific knowledge to inform the appropriate movement for goal achievement (Renshaw, Oldham, Davids, & Golds, 2007).

In conclusion, the findings of this study underline the need to develop movement models of performance in sporting environments to fully understand the representativeness of tasks designed. Providing evidence on this allows experimenters to make data driven assessments of the degree to which their tests are externally valid whilst maintaining experimental control. With this in mind, we echo the conclusions made by Starkes et al. (1995) that the methodology and findings of the current study might lead researchers away from using unrepresentative dichotomous tasks with high levels of control, and towards a balanced approach that allows for more accurate generalization to natural environments, whilst maintaining a level of experimental control.
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References


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contributing to skill in cricket batting. *Journal of Sport & Exercise Psychology*, 30, 663 – 684.


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Table 1.

Between and within-participant front foot movement magnitude standard deviations (m) for the 13 skilled batsmen in the two conditions (In-situ, Laboratory) across the five delivery lengths categories.

<table>
<thead>
<tr>
<th>Length</th>
<th>0-3m</th>
<th>3-5m</th>
<th>5-7m</th>
<th>7-10m</th>
<th>10-14m</th>
<th>Mean</th>
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<tr>
<td></td>
<td>Situ</td>
<td>Lab</td>
<td>Situ</td>
<td>Lab</td>
<td>Situ</td>
<td>Lab</td>
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Figure 2. A participant taking part in the laboratory-based cricket-batting test.

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