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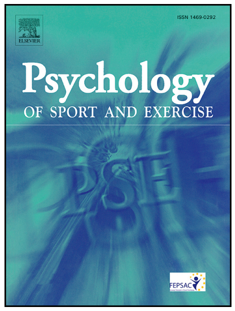

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Representative Design: Does the Addition of a Defender Change the Execution of a Basketball Shot?

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Abstract

Objective: The aim of this study was to examine the influence of a defender on the performance of a motor skill from an invasion sport.

Design: Highly skilled basketball players performed different variations of basketball shots using a randomised test schedule.

Method: Participants completed a total of 30 test trials comprising 6 trials of 5 different shot types in both defended and undefended conditions.

Results: The presence of a defender led to significant changes in several behavioral measures including faster shot execution times, longer jump times, and an increase in the amount of time that the ball spent in the air as it travelled to the basket after being released from the shooter's hand. These behavioral changes were accompanied by an overall decline in shooting accuracy of over 20%. Defended shots also tended to elicit greater amounts of movement variability which, when interpreted in conjunction with the other findings, suggests that participants were attempting to adapt their movements to accommodate for the changing demands of the performance environment. Comparisons across different shot types revealed that the influence of the defender was generally context and task dependent.

Conclusions: The results have important implications for representative task design, and highlight how the manipulation of key information sources can have a marked effect upon behavioral responses.

Keywords: Representative design; Practice design; Movement variability; Perception-action coupling; Basketball; Skill acquisition

The highly refined perceptual-motor skills exhibited by athletes in the sporting domain have been identified as a key distinguishing feature of expert performance (e.g., Abernethy & Russell, 1987; Button, MacLeod, Sanders, & Coleman, 2003; Temprado, 2002; for overviews, see Abernethy, 1994; Williams, Davids, & Williams, 1999). Theoretical explanations derived from ecological psychology propose that one of the critical factors underpinning skilled performance is the close coupling between perception and action termed the "perception-action coupling" (Davids, Araújo, Button, & Renshaw, 2007; Gibson, 1979; Gibson & Pick, 2000; Michaels & Beek, 1995; Renshaw, Davids, Shuttleworth, & Chow, 2009). Under this framework, a reciprocal relationship exists between the perceptual information used to guide movement, and the movements that help to guide the uptake of perceptual information (Gibson, 1979; Gibson & Pick, 2000; Renshaw et al., 2009). The implication is that skill acquisition requires the individual to become selectively attuned to the critical sources of information that exist within the performance environment in order to facilitate both an appropriate and timely motor response (Araújo, Davids, Bennett, Button, & Chapman, 2004; Headrick et al., 2012; Müller et al., 2009; Renshaw et al., 2009; Travassos, Araújo, Duarte, & McGarry, 2012). This is likely to be particularly important in the dynamic and fast-paced setting of many sporting contests where performers are required to continuously adapt their behavior to suit the changing task constraints (see Bartlett, Wheat, & Robins, 2007; Davids, Glazier, Araújo, & Bartlett, 2003).

The influence of the perception-action coupling on the performance of various motor tasks has been demonstrated by the findings from empirical research (e.g., Renshaw, Oldham, Davids, & Golds, 2007; for an overview see Pinder, Davids, Renshaw, & Araújo, 2011a). In experimental tasks where perceptual information has been either removed or degraded, performers have been shown to produce significantly different movement patterns compared to those used during tasks that are more representative of the target environment (e.g., Pinder et al., 2011a; Pinder, Renshaw, & Davids, 2009; Renshaw et al., 2007; Rojas, Cepero, Oña, & Gutierrez, 2000; Travassos, Duarte, Vilar, Davids, & Araújo, 2012). Such evidence not only highlights the importance of the relationship between perception and action, but it also demonstrates the potential influence of this factor in the design of experimental tasks or skill practice sessions (Pinder et al., 2011a).

The notion of "representative design" advocated by Brunswik (1956) argues that tasks should be created in such a way as to ensure that the same degree of functionality and fidelity exists in both the experimental environment and the desired target environment, thereby enabling the experimental results to be generalizable (Hammond & Bateman, 2009; Hammond & Stewart, 2001; Pinder et al., 2011a). In the inherently uncertain, dynamic, and often complex environment of many sporting contests, successful performance relies upon the capability of the performer to perceive and accurately interpret the diverse array of proximal cues (i.e., information that is readily available to the performer such as observing the specific movements of a defender) in order to infer distal events (i.e., a remote variable that cannot be directly perceived such as the specific intentions of an opponent) (Araújo, Davids, & Passos, 2007; Araújo & Kirlik, 2008; Brunswik, 1943, 1956; Chow, Davids, Button, & Renshaw, 2016; Hammond & Bateman, 2009). Thus, in the sporting domain, practice tasks should be representative of the interdependencies between the performer and the environment to enable the performer to learn the correspondence between the probabilistic (i.e., uncertain) proximal cues and the distal variables of interest (Brunswik, 1943, 1956; Araújo & Kirlik, 2008; Pinder et al., 2011a; see also Araújo, Davids, & Hristovski, 2006). This notion was investigated by Travassos, Duarte, et al. (2012) who found that the regularity (i.e., the consistency of passing speed) and the accuracy of passes executed by experienced futsal players tended to vary as a function of the representativeness of the practice task. When the task required passes to be executed in conditions with predetermined passing options (less representative task), the accuracy of the passes increased and ball speed became more regular compared to the passes observed in a competitive game. In contrast, the passes performed in practice scenarios where there were a greater number of passing options (more representative task), tended to elicit passes that were a closer match to those observed in competition, exhibiting reduced accuracy and more irregular ball speed. As the representativeness of the environment increased, so did the fidelity of behavioral responses: Passes became more variable, just like those observed in the competition environment (Travassos, Duarte, et al., 2012; see also Pinder et al., 2011a). However, while the study reported by Travassos, Duarte, et al. (2012) is one of the few to apply the concept of representative design to a practice task derived from an invasion sport (i.e., a sport where attackers invade the territory of an opponent; see Almond, 1986; Ellis, 1983; Gréhaigne, Godbout, & Bouthier, 2001), none of the experimental conditions (apart from the competitive game) included defensive players. As such, the authors recommended that future studies should attempt to include defenders to further examine the influence of this factor upon performance.

Despite the theoretical and practical implications of a comparison across defended and undefended conditions, there are only a limited number of published studies within this area (for examples, see Hughes, Watkins, & Owen, 2010; Orth, Davids, Araújo, Renshaw, & Passos, 2014; Rivilla-Garcia, Grande, Sampedro, & van den Tillaar, 2011; Rojas et al., 2000; van der Wende, 2005). Of the studies that exist, the results have shown that players tend to change their movement pattern to adapt to the demands created by the presence of a defender (e.g., Hughes et al., 2010; Rivilla-Garcia et al., 2011; Rojas et al., 2000). For example, Rojas et al. (2000) found that the action responses of professional basketball players were tightly coupled to the presence of a defender. When performing jump shots against a defender, the release angle of the ball, and the vertical velocity of the ball during the initial elevation phase of the shot, were greater compared to the values observed in an undefended condition. The authors summarised their results by suggesting that the presence of a defender encouraged the players to increase the speed and release height of the ball, both of which were likely to be adaptations designed to prevent the defender from blocking the shot (see also Rivilla-Garcia et al., 2011; van der Wende, 2005). In invasion sports such as basketball, where the close proximity of players can mean that a defender is able to have a considerable perturbing effect upon the actions of an attacker, tasks requiring the performer to execute a skill against an opponent may provide a more representative design that generalizes to the target environment (Rojas et al., 2000; see also Brunswik, 1956; Pinder et al., 2011a).

In addition to preserving the ecological validities of distal and proximal cues, the study of performer-environment interactions should also sample multiple variations of the task to which findings are to generalize (Brunswik, 1956). While the investigation conducted by Rojas et al. (2000) detailed the movement adaptations that occur in the presence of a defender, the study featured a blocked design where only one variation of the basketball shot was performed repeatedly (for similar examples, see Hughes et al., 2010; McLean, Lipfert, & van den Bogert, 2004). Representative design argues that tasks should be sampled from the target environment in the same way as participants are sampled from the target population (Brunswik, 1943, 1956; Hammond & Bateman, 2009; Hammond & Stewart, 2001). Task sampling considers a wide range of relevant task variations performed in a randomised fashion (Brunswik, 1943; 1955). For instance, when assessing a single stimulus variable such as a defender, task sampling would include a representative set of situations and conditions where the defender would act as a perceptual variable (Brunswik, 1943). Thus, performing blocked repetitions of a single task from an invasion sport is, in itself, non-representative, and so responses may be different to those required in a more randomised (representative) environment containing several task variations (see Pinder et al., 2011a). The use of a randomised design that includes several variations of a motor task could also help to determine whether certain variables elicit more changes in movement behaviors than others. Previous research has shown that variations of the same task, differing only by defender proximity and the positioning of players relative to the scoring zone, can have a marked influence on the movement characteristics of performers (see Headrick et al., 2012; Orth et al., 2014). For example, when the defender is in close proximity to an attacker during a cross pass to a team-mate in soccer, the average running velocity of the attacker increases and the speed of the attacker's kick decreases, compared to when the same scenario is performed with the defender positioned at a greater distance from the attacker (Orth et al., 2014). Similarly, the relative proximity to goal of an attacker competing against a defender in soccer has also been shown to influence player behaviors, with closer proximities exhibiting significantly different behaviors compared to more distant proximities (Headrick et al., 2012). This evidence suggests that the degree of defensive perturbation that can be exerted by an opponent may vary, depending upon the nature of the constraints and the ways in which they impact upon the performance of the task (Headrick et al., 2012; Orth et al., 2014). This rich understanding of organismic behavior in these contexts is only possible through these researchers sampling multiple variations of the same task (see Brunswik, 1956).

Finally, an interesting aspect of performance that has only rarely been considered in studies comparing defended and undefended motor tasks is movement variability (e.g., van der Wende, 2005; see also McLean et al., 2004). Given that the presence of a defender has been shown to induce certain adaptive behaviors on the part of the attacker (e.g., Rojas et al., 2000; van der Wende, 2005), it is necessary to determine whether such behaviors are also accompanied by higher levels of movement variability (see McLean et al., 2004; van der Wende, 2005). A more variable movement pattern may be indicative of an individual's attempts to adapt to the changes that occur within the performance environment (Davids et al., 2003). Thus, if defended conditions promote more variable movements, this would suggest that such tasks may provide useful practice opportunities to promote the acquisition of functionally adaptable movement patterns (see Barris, Farrow, & Davids, 2014; Davids et al., 2003). Given that the dynamic nature of invasion sports ensures that task and environmental constraints are constantly fluctuating, and even highly repetitive tasks contain movement variations (for overviews, see Bartlett et al., 2007; Davids et al., 2003), it is important to investigate the extent of the movement variability that is exhibited when competing against a defender under randomised variations of the same motor task.

The purpose of the present study was to examine the influence of a defender on the performance of a basketball shot using a randomised test schedule sampling five different shot types. The accuracy of the shots were recorded, along with several behavioral measures including shot execution time, jump time, and ball flight time. Movement variability was also analysed by examining the standard deviations of each of the aforementioned behavioral measures (for similar approaches, see Bootsma, 1989; McDonald, van Emmerik, & Newell, 1989; McLean et al., 2004; Vaughn & Kozar, 1993). It was anticipated that defended and undefended conditions would elicit significant differences in each of the measured variables, but that the differences would be more pronounced for shots where the defender was able to have a greater perturbing effect on the attacker (see Orth et al., 2014). The changes exhibited by the attacker in the defended conditions were also expected to be consistent with those required for the attacker to adapt his shot to prevent it from being blocked by the defender (see Rojas et al., 2000; van der Wende, 2005). The defended conditions were therefore predicted to have higher levels of movement variability compared to the undefended conditions (see Rojas et al., 2000; van der Wende, 2005).

Method

Participants

A total of 12 highly skilled junior male basketball players participated in the study. The average age of participants was 17.80 years (*SD* = 1.15 years). Participants were members of a national elite junior development squad and had an average of 10.58 years (*SD* = 2.91 years) of playing experience. All playing positions were represented in the study including guards, forwards, and centres. The study received institutional ethical approval and informed written consent was provided.

Procedure

Participants were allocated into matched pairs for testing. The composition of each pair was determined using the judgement and guidance of the players' current coaches. The coaches based their judgements upon each player's skill level and the players' usual playing position. Immediately prior to each test occasion, the pairs performed a brief warm-up until both participants reported that they were ready to begin testing. Each pair performed both an undefended shooting test and a defended shooting test with the two test conditions being counterbalanced across pairs. Both conditions were designed to be identical, apart from the inclusion of an opponent in the defended version of the test. To avoid any potential issues related to fatigue, the defended and undefended tests were performed on different days. Players were encouraged to perform the tasks within the tests in a gamelike manner with the same level of intensity that they would ordinarily exhibit in a game. A total of 30 test trials were completed in both the defended and undefended conditions, and these comprised six trials of five different shot types. The location and nature of each shot are described below.

3-point shot. The shooter stood outside the 3-point line and received a pass from his partner who was standing inside the charge circle. The shooter was permitted to shoot the ball immediately after receiving the pass. In the defended condition, the passer was required to run out to defend the shooter, but only after the ball had been released from the passer’s hands. This allowed sufficient time for the passer to reach the shooter and contest the shot. There were five different shooting locations for this shot type including one shot from each of the left and right corners of the court, two shots from directly in front of the basket, and one shot from each of the left and right wings (i.e., 45 degree angle to the basket).

Free throw. The shooter performed his preferred pre-shot routine before executing a single free throw. The shooter’s partner stood just outside the key at the top hash mark and on the right hand side of the basket. Given that a free throw in basketball is essentially an uncontested shot (International Basketball Federation, 2014), the defended version simply required the defender to step into the key and position himself in front of the shooter immediately after the ball had left the shooter’s hand, as is permitted under normal basketball rules (see International Basketball Federation, 2014).

Post move. The shooter stood just in front of the charge circle with the ball in his hands and his back to the basket. To initiate the shot, the shooter was instructed to throw the ball into the air so that it bounced off the floor and spun back into his hands. The shooter was required to receive the ball with one foot inside the charge circle and one foot outside the charge circle. Dribbling the ball was not permitted. The defended version was identical except on this occasion, the defender was positioned directly behind the shooter. Once the shooter caught the ball after it had bounced off the floor, the situation was considered to be “live” and the defender was instructed to attempt to prevent the shooter from scoring. Two shots were performed from both the left and right sides of the charge circle, and two shots were performed from directly in front of the basket.

Pull-up jumper. The shooter was positioned just outside the 3-point line where he received a pass from his partner. The partner stood on the baseline of the court where the line from the opposite side of the key intersected the baseline. Immediately after receiving the pass, the shooter was required to execute a single dribble, either left, right, or straight ahead, before initiating a jump shot (a shot that is executed while the player is in mid-air) from inside the 3-point line. The defended version required the passer to run out to defend the shooter immediately after the ball had been released from the passer's hands. Three shots were performed from both the left and right wings of the court, which were at 45 degree angles to the basket.

Screen and curl cut. The shooter started each trial standing on the baseline of the court at the location where the line from the key intersected with the baseline. The shooter initiated the trial by sprinting away from the basket and running along the line of the key towards a chair positioned on the top hash mark of the key. The chair acted as a substitute for a screen from a team-mate. The shooter was required to run around the chair (i.e., curl cut) before receiving a pass delivered by a member of the research team. The shooter received the pass while he was positioned on or close to the free throw line. Immediately after receiving the pass, the shooter was required to execute a jump shot. The shooter was not permitted to dribble the ball. The defended condition was performed in an identical manner but with a defender chasing directly behind the shooter. The defender was instructed to run around the chair, in pursuit of the shooter, and to attempt to defend the shot. Three shots were performed from both the left and right sides of the court.

The series of shots outlined above were performed in the same trial order for each participant and for each test occasion (i.e., 3-point, free throw, post move, pull-up jumper, and screen and curl cut). However, to create a more representative test environment, no two shot types were performed in a row. The location of each shot type was also varied (apart from the free throw which was performed at the same location for all trials). The players in the pairs alternated between shooter and passer/defender after every shot. Regulation basketball rules applied for all shots (see International Basketball Federation, 2014).

However, if the shooter was fouled by his partner, or if the pass delivered to the shooter was deemed to have substantially disadvantaged the shooter, the trial was repeated. To maintain greater consistency within the test conditions, no shot fakes were allowed at any time during the test. The test took approximately 20 min to complete and a standard sized basketball (size 7) and a regulation court were used for all trials. Two digital cameras (capturing at 25 frames per second) were used to record each shot attempt to allow a post hoc frame-by-frame analysis of each test trial. One camera was positioned just outside the sideline and in line with the free throw line on the right side of the court (when facing the basket). The second camera was also positioned on the right side of the court at the point where the centreline intersected with the sideline.

Data Analysis

The number of successful shot attempts recorded during testing were summed and divided by the total number of test trials to provide an overall percentage score for *shooting accuracy* across the defended and undefended conditions. Three other dependent variables were extracted from the video recordings captured during testing. *Shot execution time* was defined as the time taken to perform the shot and was measured from the moment when the ball first touched either of the shooter's palms, to the moment when the ball first lost contact with the shooter's hand during the execution of the shot. This variable was not computed for the free throw because the shot itself was self-timed and not subject to the same time pressures as the other shot types. *Jump time* was defined as the amount of time the shooter was in the air during the shot and was measured from the moment when both of the shooter's feet first left the floor, to the moment when either of the shooter's feet first resumed contact with the floor. Larger values for jump time were considered to be indicative of a higher jump during the execution of the shot. Jump time was not calculated for the free throw because this shot type is usually performed without jumping. *Ball flight time* was defined as the flight time of the ball after it was released from the shooter's hand and was measured from the moment when the ball left the shooter's hand, to the moment when the ball first touched (or would have touched) either the ring or backboard.

Statistical analyses included separate 2-way repeated measures analysis of variance (ANOVA) tests for each of the dependent variables which included accuracy, shot execution time, jump time, and ball flight time. Condition (defended and undefended) and shot type (3-point, free throw, post move, pull-up jumper, and screen and curl cut) were the independent variables. To examine whether the defended and undefended conditions exhibited differences in the variability of the shooting action, 2-way (Condition x Shot Type) repeated measures ANOVAs were also conducted using the standard deviations for shot execution time, jump time, and ball flight time. Post hoc comparisons for main effects were conducted using Sidak corrections, and significant interactions were followed-up using paired *t*-tests. The assumption of normality was assessed using significance tests of skewness and kurtosis where values above an alpha level of .001 were considered to be significant departures from a normal distribution (see Tabachnick & Fidell, 2001). A log transformation (base 10) was used to achieve normality for the standard deviation data for shot execution time and ball flight time (note that the means for the transformed data in the results are denoted as M_t). Greenhouse-Geisser corrections were used for any violations of the assumption of sphericity. Effect sizes for paired *t*-tests (expressed as *d*) were computed using the *t* statistic, the correlation between the paired samples, and the sample size (see Dunlap, Cortina, Vaslow, & Burke, 1996; Dunst, Hamby, & Trivette, 2004). Sample size calculations for condition and shot type were conducted using the repeated measures within factors function in G*Power (Faul, Erdfelder, Lang, & Buchner, 2007) with power set at .80, alpha set at .05, and the effect size based upon those reported in similar research (see Orth et al., 2014; Rivilla-Garcia et al., 2011; van der Wende, 2005). The analysis revealed that a sample size of 10 would provide sufficient power for the study. Only the statistical analyses required to test the hypotheses of interest are included in the results and so post hoc comparisons for significant main effects for shot type are not reported.

Results

Shooting Accuracy

There were significant main effects for condition, *F*(1, 11) = 35.56, $p < .001$, $\eta_p^2 = .76$, and shot type, *F*(4, 44) = 18.40, $p < .001$, $\eta_p^2 = .63$. The shooting accuracy of participants was significantly lower in the defended conditions (*M* = 41.1%) compared to the undefended conditions (*M* = 63.9%). A significant Condition x Shot Type interaction, *F*(4, 44) = 5.58, $p = .001$, $\eta_p^2 = .34$ (see Figure 1), indicated that the shooting accuracy in the defended condition was significantly lower than that observed in the undefended condition for the post move, *t*(11) = -8.25, $p < .001$, *d* = -2.41, pull-up jumper, *t*(11) = -4.18, *p* = .002, *d* = -1.91, and screen and curl cut, *t*(11) = -3.17, *p* = .009, *d* = -1.04. There were no significant differences between the defended and undefended conditions for the 3-point shot, *t*(11) = -0.15, *p* = .88, *d* = -0.08, and the free throw, *t*(11) = -0.69, *p* = .50, *d* = -0.32.

Insert Figure 1 about here

Shot Execution Time

There were significant main effects for condition, *F*(1, 11) = 12.47, *p* = .005, $\eta_p^2 = .53$, and shot type, *F*(1.47, 16.18) = 74.90, $p < .001$, $\eta_p^2 = .87$. Shots executed under defended conditions (*M* = 0.99 s) were performed significantly faster than those executed in undefended conditions (*M* = 1.08 s). A significant Condition x Shot Type interaction, *F*(1.47, 16.13) = 8.45, *p* = .006, $\eta_p^2 = .43$ (see Figure 2), revealed that the shot execution time for the defended condition was significantly faster than that observed in the matched undefended condition for the 3-point, *t*(11) = -6.64, $p <.001$, *d* = -1.27, pull-up jumper, *t*(11) = -6.50, $p <.001$, *d* = -2.06, and screen and curl cut, *t*(11) = -2.41, *p* = .034, *d* = -0.72. There were no significant differences in shot time between the defended and undefended post move, $t(11) = 1.27$, $p = .23$, $d = 0.44$.

The ANOVA examining the variability for shot execution time showed significant main effects for condition, $F(1, 11) = 20.25$, $p = .001$, $\eta_p^2 = .65$, and shot type, $F(3, 33) = 13.7$, $p < .001$, $\eta_p^2 = .56$. The variability in shot execution time was significantly greater in the defended conditions ($M = 0.16$, $M_t = -0.98$) compared to the undefended conditions ($M = 0.07$, $M_t = -1.17$). A significant Condition x Shot Type interaction, $F(3, 33) = 9.48$, $p < .001$, $\eta_p^2 = .46$, revealed greater variability for the shot execution time in the defended condition compared to the undefended condition for the post move, $t(11) = 5.48$, $p < .001$, $d = 2.29$, and pull-up jumper, $t(11) = 2.49$, $p = .03$, $d = 0.88$, with the screen and curl cut approaching significance, $t(11) = 1.97$, $p = .07$, $d = 0.41$.

Insert Figure 2 about here

Jump Time

There were significant main effects for condition, $F(1, 11) = 9.18$, $p = .01$, $\eta_p^2 = .46$, and shot type, $F(1.67, 18.34) = 27.89$, $p < .001$, $\eta_p^2 = .72$. Participants spent significantly longer in the air in the defended conditions ($M = 0.43$ s) compared to that observed in the undefended conditions ($M = 0.40$ s). A significant Condition x Shot Type interaction, $F(3, 33) = 25.78$, $p < .001$, $\eta_p^2 = .70$ (see Figure 3), indicated that the jump time for the defended condition was significantly longer than that observed in the matched undefended condition for the 3-point, $t(11) = 2.54$, $p = .027$, $d = 0.46$, pull-up jumper, $t(11) = 4.43$, $p = .001$, $d = 1.03$, and screen and curl cut, $t(11) = 6.07$, $p < .001$, $d = 1.63$. In contrast, the jump time for the post move was significantly longer in the undefended condition compared to that exhibited in the defended condition, $t(11) = -3.64$, $p = .004$, $d = -1.10$.

In terms of the variability of jump time, there was a main effect for shot type, $F(3, 33) = 2.96$, $p = .046$, $\eta_p^2 = .21$. However, pairwise comparisons were not significant after the application of Sidak adjustments.

Insert Figure 3 about here

Ball Flight Time

Significant main effects were present for condition, $F(1, 11) = 46.58$, $p < .001$, $\eta_p^2 = .81$, and shot type, $F(2.16, 23.77) = 360.93$, $p < .001$, $\eta_p^2 = .97$. The flight time of the ball was longer in duration for the defended conditions ($M = 0.96$ s) compared to the undefended conditions ($M = 0.83$ s). There was also a significant Condition x Shot Type interaction, $F(2.13, 23.46) = 17.03$, $p < .001$, $\eta_p^2 = .61$ (see Figure 4), which showed that the ball flight time for the defended condition was significantly longer than that exhibited in the undefended condition for the 3-point, $t(11) = 3.16$, $p < .001$, $d = 1.14$, post move, $t(11) = 6.44$, $p < .001$, $d = 2.28$, pull-up jumper, $t(11) = 4.91$, $p < .001$, $d = 0.88$, and screen and curl cut, $t(11) = 4.17$, $p = .002$, $d = 1.36$. There were no significant differences between the defended and undefended versions of the free throw, $t(11) = 1.23$, $p = .24$, $d = 0.25$.

The analysis of the variability of ball flight time revealed main effects for condition, $F(1, 11) = 9.90$, $p = .009$, $\eta_p^2 = .47$, and shot type, $F(4, 44) = 23.17$, $p < .001$, $\eta_p^2 = .68$. The variability of ball flight time was greater in the defended conditions ($M = 0.08$, $M_t = -1.18$) compared to the undefended conditions ($M = 0.05$, $M_t = -1.36$).

Insert Figure 4 about here

Discussion

The purpose of this study was to examine the changes that occurred when a motor skill from an invasion sport was performed in the presence and absence of a defender. Skilled basketball players executed five different shot types in a randomised schedule under both defended and undefended conditions. As predicted, a number of differences emerged between the two conditions, with the results showing that the presence of a defender tended to elicit significant and variable changes to the way in which the attacker executed his shot. In general, when required to shoot against an opponent, participants increased the amount of time they spent in the air during their shot, increased the overall speed to execute their shot, and increased the amount of time that the ball spent in the air before it contacted the basket after being released from the shooter's hand. Participants also adopted more variable movement solutions. These behavioral changes were accompanied by an overall decline in shooting accuracy of more than 20 percent.

The results further highlight the close links between perception and action and the influence of this factor when attempting to design and implement representative practice tasks (see Pinder et al., 2011a; Rojas et al., 2000). In particular, it seems that the removal of certain sources of perceptual information from an invasion sport task, in this instance, the movements of the defender (e.g., the defender's hand position and foot placement), alters the movement behavior of attacking players performing a basketball shot. This behavior is significantly different to that observed under more representative conditions (i.e., when a defender is present). These conclusions are consistent with those reported previously by Rojas et al. (2000) for basketball, as well as for research conducted in other invasion sports including handball (Rivilla-Garcia et al., 2011) and water polo (van der Wende, 2005). In these studies, participants changed the way in which they performed a given task when that task was executed in the presence of a defender. However, the present study was also aimed at advancing this research by conducting a direct comparison of defended and undefended conditions using a randomised schedule with several variations of the same motor task. The results therefore extend the extant literature by showing that the changes induced by the presence of a defender are also likely to occur when variations of the same motor task are performed in a randomised manner across a variety of different situations. The contextualised nature of these changes across task variations highlights the importance of task sampling; that is, sampling variations of the same task to ensure the generalizability of results (Brunswik, 1943, 1955).

The other benefit of conducting a comparison across different shot types was that it provided an opportunity to examine whether certain variations of a task elicit more pronounced changes in performance than others. The results revealed that performance changes were linked to the dynamic nature of the task. The free throw, which provided very limited opportunities for the defender to perturb the shooter, showed no significant differences between the defended and undefended conditions. At the other end of the continuum, the pull-up jumper and the screen and curl cut, which were the two most dynamic task variations, showed significant changes in all of the measured variables across the defended and undefended conditions. For the post move and 3-point shot, which were likely to have been perturbed to a lesser extent than the pull-up jumper and the screen and curl cut, but to a greater extent than the free throw, the performance changes tended to vary across the different experimental measures. The post move showed no significant differences in the time taken to execute the shot in the defended condition, but all other variables were significantly different between the defended and undefended conditions. The post move was also the only shot type to show a decrease in jump time for the defended condition, possibly because many of the participants elected to dunk the ball in the undefended condition (thereby requiring a higher jump), which was usually not a feasible option in the defended condition due to the positioning of the defender. For the 3-point shot, there was no significant change in shooting accuracy for the defended condition, but shot execution time, jump time, and ball flight time were all significantly different. It seems that the participants were able to successfully adapt their movements to maintain the accuracy of their 3-point shots, suggesting that the adaptations were of a highly functional nature. The different results observed for each shot highlight the importance of sampling a variety of tasks from the target environment (Brunswik, 1943, 1956). Experiments that neglect task sampling may provide only a limited basis for understanding whether results are representative or anomalous of behavior (Brunswik, 1955).

In general, participants appeared to organise their movement behavior in response to those of the defender: The greater the perturbing effect of the defender, the more changes that were elicited during the performance of the task. That is, the increased potential for the defender to perturb the pull-up jumper and screen and curl cut (due to the close proximity of the defender and the increased ease with which the defender could use his hand to attempt to block the shot) revealed that a higher degree of defensive pressure during these shots tended to elicit significantly greater changes in performance compared to the free throw shot where the defender was less able to perturb the shooter (due to the rule restrictions imposed upon the movements of the defender; see International Basketball Federation, 2014). Moreover, the 3-point shot and post move, which were located somewhere between the other shot types in terms of the degree of defensive perturbation that was able to be exerted by the defender (due to the reduced proximity of the defender to the shooter for the 3-point shot, and the close proximity to the basket of the shooter for the post move), appeared to be influenced by the defensive pressure in specific ways, exhibiting changes in some variables and not others. These results are consistent with those reported previously for soccer where the behaviors of an attacker changed significantly when the nature of the task was altered by varying the proximity of the defender to the attacker (Orth et al., 2014), or by changing the location of players relative to the scoring zone (Headrick et al., 2012).

The underlying nature of the changes that were exhibited in the present study may be indicative of the participants' attempts to adapt their movements to accommodate for the behaviors of the defender (see Rojas et al., 2000; van der Wende, 2005; see also Davids et al., 2003; Handford, Davids, Bennett, & Button, 1997). Participants tended to increase the overall speed of the execution of their shot, increase the amount of time they spent in the air during the jump phase of their shot, and increase the amount of time that the ball was in flight as it travelled towards the basket (see also Rojas et al., 2000). In practical terms, these changes were likely to represent a faster catch and release of the ball, a higher jump, and a more pronounced arc on the trajectory of the ball, all of which exemplify logical adaptations that may have been used by participants to help prevent the defender from blocking their shot (see Rojas et al., 2000). One of the reported attributes of skilled performers is their capability to adapt their movements to accommodate for the changing demands of the performance context (Davids, Button, & Bennett, 2008; Newell, 1985). This notion is consistent with the results of the present study, and also those reported in previous research examining the influence of defensive pressure in team sport tasks (e.g., Rojas et al., 2000; van der Wende, 2005). For example, Rojas et al. (2000) revealed that when shooting against opposition, skilled basketball players increased the velocity of their movements during the early phase of their shot, and released the ball at a greater angle and from a greater height compared to when shooting in an unopposed condition (Rojas et al., 2000). Similarly, elite level water polo players were found to increase the overall speed of their shooting movement and alter the placement of their shots at goal when competing against a defender, compared to when they performed in an undefended control condition (van der Wende, 2005).

The adaptability of skilled athletes is also typically associated with increased levels of movement variability which is believed to occur as a result of the individual's attempts to adjust to the changes in the performance environment (for overviews, see Bartlett et al., 2007; Davids et al., 2003; Handford et al., 1997). The variable movements are therefore believed to play an important functional role in helping to ensure the success of the final outcome of a given task (Davids et al., 2003). To further examine the adaptability exhibited by participants when competing against an opponent, movement variability was compared across the defended and undefended conditions for each shot type (see also van der Wende, 2005). Overall, there was significantly more variability in shot execution time and ball flight time for the defended conditions compared to the undefended scenarios. The shot execution time for the defended conditions also revealed a trend towards more variability for the shot types that were subject to higher levels of defensive perturbation. Van der Wende (2005) showed that elite water polo players also had increased levels of movement variability during certain phases of their shooting action when performing in the presence of a defender and/or goalkeeper, compared to shots performed in an undefended scenario. These results, and those of the present study, suggest that skilled team sport performers tend to significantly increase the variability of their movements when performing under defensive pressure, compared to when they perform an identical task in the absence of a defender (van der Wende, 2005).

The increased levels of variability may exemplify the participants' attempts to adapt their shots when competing against an opponent (van der Wende, 2005). Alternatively, it could also be argued that the overall decline in shooting accuracy of over 20% that was observed in the present study during the defended conditions (with the exception of the 3-point shot and free throw), may indicate that the increased movement variability was not always functional in nature (see also van der Wende, 2005). However, given that the significant changes in jump height, shot execution time, and ball flight time were all indicative of logical adaptations to help prevent the defender from blocking their shot (see Rojas et al., 2000), the reduced shooting accuracy may simply be a result of the player's inability to convert their adaptations into a successful outcome. In other words, the participants were attempting to vary their movements to adapt to the presence of the defender, but their adaptations were not sufficiently well learned and were therefore not always successful. Further research in this area is required to help confirm these conclusions, particularly given the limited number of studies investigating the movement variability that occurs during the performance of a task from a team sport while in the presence of a defender (see McLean et al., 2004; van der Wende, 2005).

In conclusion, and in line with the tenets of representative design, the results from this, and several other studies, suggest that the inclusion of opponents may be an important ecological constraint for maintaining the representativeness of experimental designs and practice tasks when working with team sports (Pinder et al., 2011a; Pinder, Headrick, & Oudejans, 2015; Renshaw, Davids, Shuttleworth, & Chow, 2009; Rojas et al., 2000; van der Wende, 2005). The varying nature of the responses displayed within the results of this study suggests that the perturbing effect of a defender is context and task dependent (see also Headrick et al., 2012; Orth et al., 2014). This may afford different movement responses, providing an explanation as to why variability increased in the defended task (see Bartlett et al., 2007; Davids et al., 2003; van der Wende, 2005). Such tasks are more likely to preserve the coupling between perception and action, thereby providing opportunities for performers to become closely attuned to the key information sources that guide and influence their behaviors (Beek, Jacobs, Daffertshofer, & Huys, 2003; Jacobs & Michaels, 2002; Renshaw et al., 2009). This is an important consideration when designing representative tasks for invasion sports, particularly given that the actions of an attacker can be influenced by a range of different perceptual features including the proximity of the defender's positioning, the defender's height, or the orientation of the defender's feet (see Cordovil et al., 2009; Esteves, de Oliveira, & Araújo, 2011; Passos, Araújo, Davids, Gouveia, Milho, & Serpa, 2008; see also Araujo et al., 2006). Moreover, the increased movement variability that occurs as a result of competing against a defender may also provide useful practice tasks to promote the acquisition of functionally adaptable movements (see Barris et al., 2014; Davids et al., 2003; van der Wende, 2005).

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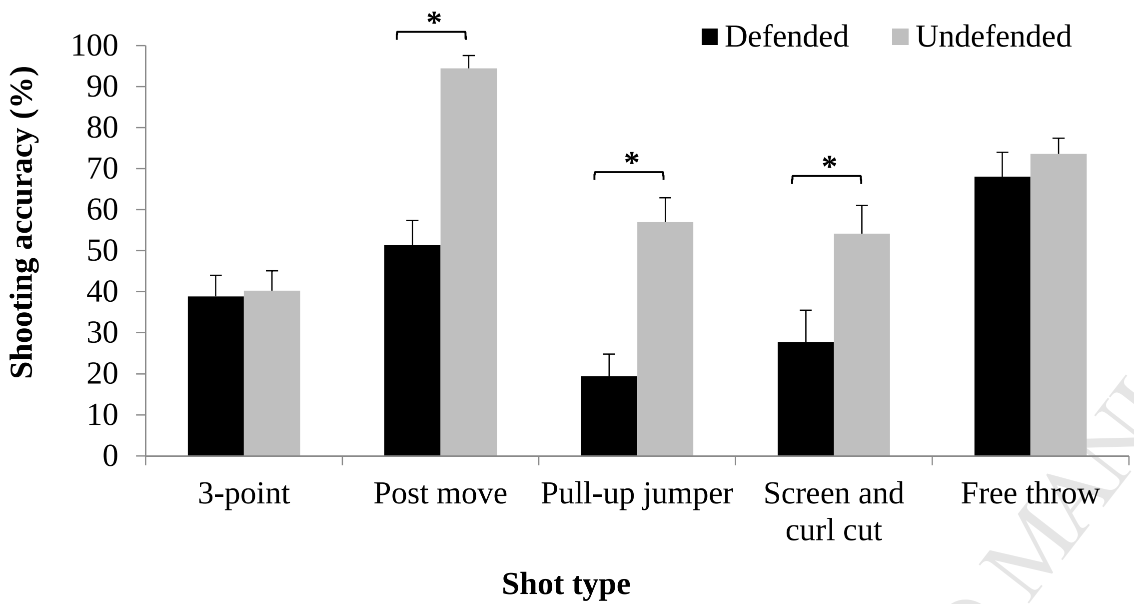
Figure Captions

Figure 1. Mean shooting accuracy for each shot type across the defended and undefended conditions. Error bars show standard error. Significant differences ($p < .05$) between defended and undefended conditions for a given shot type are denoted by an asterisk.

Figure 2. Mean shot execution time for each shot type (excluding free throw) across the defended and undefended conditions. Error bars show standard error. Significant differences ($p < .05$) between defended and undefended conditions for a given shot type are denoted by an asterisk.

Figure 3. Mean jump time for each shot type (excluding free throw) across the defended and undefended conditions. Error bars show standard error. Significant differences ($p < .05$) between defended and undefended conditions for a given shot type are denoted by an asterisk.

Figure 4. Mean ball flight time for each shot type across the defended and undefended conditions. Error bars show standard error. Significant differences ($p < .05$) between defended and undefended conditions for a given shot type are denoted by an asterisk.


Defended
Undefended
Shooting accuracy (%)
100
90
80
70
60
50
40
30
20
10
0
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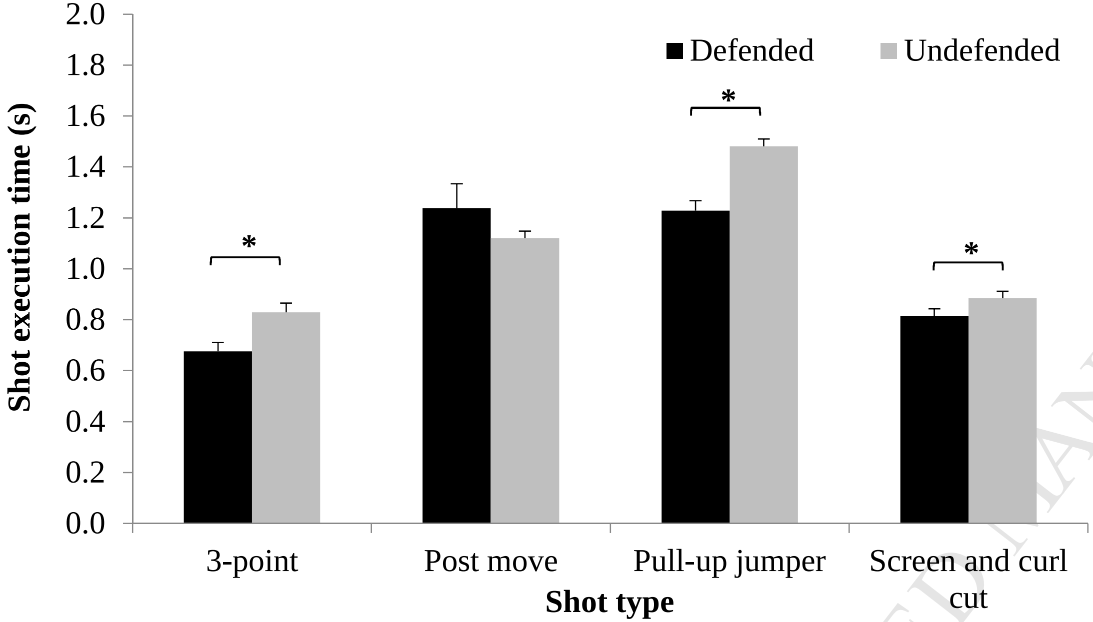
3-point
Post move
Pull-up jumper
Screen and curl cut
Free throw
Shot type


2.0
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Screen and curl cut
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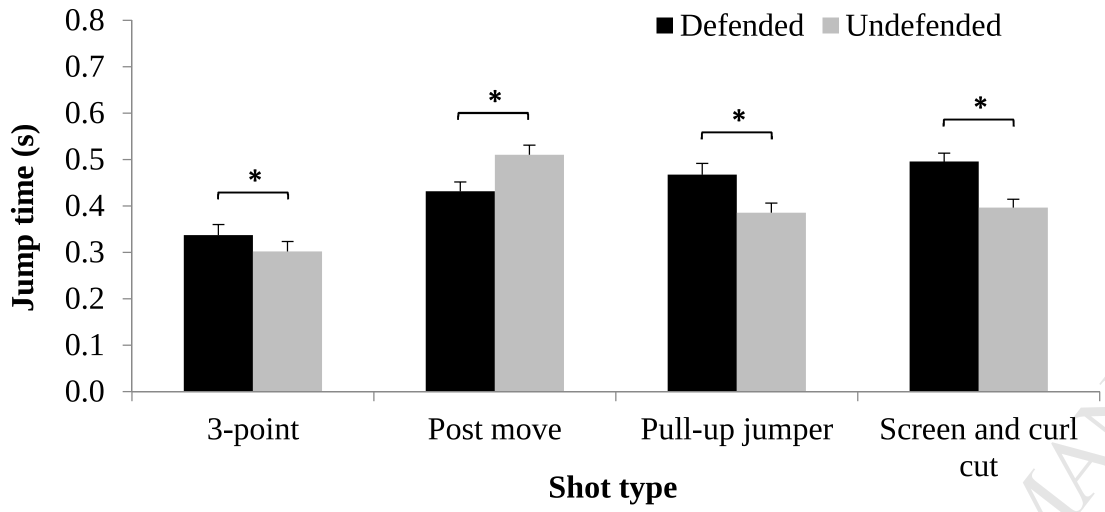
Defended
Undefended
Jump time (s)
0.8
0.7
0.6
0.5
0.4
0.3
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3-point
Post move
Pull-up jumper
Screen and curl cut
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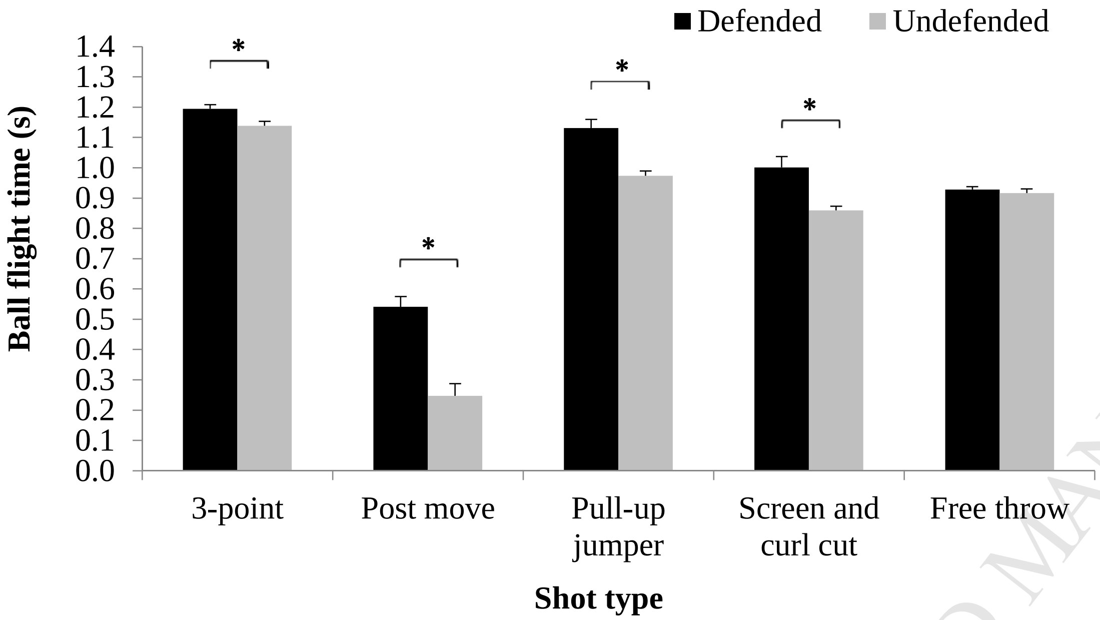

Defended
Undefended
Ball flight time (s)
1.4
1.3
1.2
1.1
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
*
*
*
*
3-point
Post move
Pull-up jumper
Screen and curl cut
Free throw
Shot type

Highlights

- Basketball shots performed against a defender elicited significant behavioral changes.
- Defended shots tended to be associated with higher levels of movement variability.
- Shooters adapted their movements to accommodate for the changing task constraints.
- Different shot types revealed different behavioral responses from the shooters.
- Representative design is important for experiments and practice tasks.