Expertise differences in anticipatory judgements during a temporally and spatially occluded dynamic task

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Abstract

There is contradictory evidence surrounding the role of critical cues in the successful anticipation of penalty kick outcome. In the current study, skilled and less-skilled soccer goalkeepers were required to anticipate spatially (full body; hip region) and temporally (–160 ms, –80 ms before, foot–ball contact) occluded penalty kicks. The skilled group outperformed the less-skilled group in all conditions. Both groups performed better in the full body, compared to hip region condition. Later temporal occlusion conditions were associated with increased performance in the correct response and correct side analysis, but not for correct height. These data suggest that there is enough postural information from the hip region for skilled goalkeepers to make highly accurate predictions of penalty kick direction, however, other regions are needed in order to make predictions of height. These data demonstrate the evolution of cues over time and have implications for anticipation training.

Keywords: anticipation, advance cue utilisation, occlusion, soccer,

In sport, the inherent limitations in reaction time and movement time necessitates that athletes anticipate or predict future events based on limited preparatory information (Hagemann, Strauss, & Cañal-Bruland, 2006). In order to effectively deal with such constraints, athletes possess a wide range of perceptual-cognitive skills, including the ability to: recognize advance (i.e., early arising) visual information (or cues); identify patterns/structure in play; and develop an awareness of likely event probabilities (Causer, Janelle, Vickers, & Williams, 2012). An expert athlete can limit the volume of information processed to generate a perceptual representation by selectively attending to more pertinent cues (Williams, Huys, Cañal-Bruland, & Hagemann, 2009). Furthermore, task-specific knowledge developed through experience is thought to help expert players look at these more important areas of the environment, using previous experiences to develop situational probabilities and allowing more effective processing of contextual information (Williams, 2009). The aim in the current study was to examine expertise differences in cue utilization in soccer penalty-kicks by manipulating the information available using temporal and spatial occlusion paradigms.

The availability of cues and time they become available will directly influence a performer's perceptual strategy and ultimately the outcome of their action (Causer & Williams, 2013). Representative tasks paired with occlusion paradigms have traditionally been used to examine perceptual-cognitive skills (Williams & Ericsson, 2005). Temporal occlusion involves editing a film into specific time phases where progressively more of a movement is presented. This paradigm has also been frequently used to distinguish between skill levels in advance cue utilization (Jackson, Warren, & Abernethy, 2006). Researchers have consistently reported that performance in later temporal occlusion conditions has been significantly higher. This finding may be due to the availability of more important cues in the later stages of a movement, or it has been suggested that an increased viewing time in the

later conditions allows the player to access more cues in the whole movement and not respond to just the cues near the end of the movement (Farrow *et al.,* 2005). The temporal occlusion approach can only indicate to the researcher at what time frame the cues were utilized, not what cues were utilized (Williams, Davids, & Williams, 1999). An alternative approach is the spatial/event occlusion paradigm, which is a technique that masks an important area/cue in the visual field to examine how it affects cue utilization or information pick-up (Williams & Davids, 1998). A decrease in performance suggests that the occluded area contains key information concerning that particular movement (Causer & Williams, 2013). A combination of these paradigms could be used to identify critical cues associated with successful anticipation, as well as the time-course of cue availability.

Due to the limits of human reaction time (Le Runigo, Benguigui, & Bardy, 2010) and the considerable temporal demands of the soccer penalty-kick (Hughes & Wells, 2002; Kuhn, 1988) goalkeepers must anticipate ball direction before it is kicked. Therefore, researchers have endeavoured to determine skill-based differences in the use of visual cues emanating from the kicker. However, there has been considerable debate into the most effective areas to fixate gaze when attempting to anticipate a soccer penalty-kick.

Early research highlighted the importance of the angle run-up, the arc of the leg on approach to the ball, and angle of the kicking foot and hips prior to ball contact (Williams & Burwitz, 1993). In contrast, follow-up studies revealed that expert goalkeepers spent a higher proportion of time fixating on both the non-kicking and kicking leg rather than the hips, while novices predominantly fixated on the, arms, trunk and hips (Savelsbergh, van der Kamp, Williams, & Ward, 2005; Savelsbergh, Williams, van der Kamp, & Ward, 2002). Kinematic analyses have cited the angle of the hips and kicking foot as reliable predictors of ball direction (Diaz, Fajen, & Phillips, 2012). A more recent kinematic analysis has demonstrated that important predictive cues evolve over the movement and are all located in the lower part

of the body (Lopes, Jacobs, Travieso, & Araújo, 2014). Specifically, at 150 ms before ball contact the non-kicking foot angle, the knee angle of the kicking leg, and the speed of the kicking foot are important. Whereas at ball contact, the kicking foot angle, the hip angle, and the movement direction of the kicking foot are more important.

Despite the contradictory evidence above, there seems to be some consistency in the importance of the hip region. Goalkeepers have reported the orientation of the hips to be useful in determining penalty-kick direction (Williams & Burwitz, 1993). Specifically, if the ball is directed to the goalkeepers left (assuming a right-footed penalty-taker), the hips slope away from the goalkeeper, whereas if the ball is travelling right the hips are square to the goal. Further support for the role of the hip region in penalty-kick anticipation was provided by Causer and Williams (2015), who manipulated cues in the region. Playing uniforms were developed that used patterns to disrupt the alignment of the hips. Performance significantly decreased in the experimental conditions compared to a control uniform. These data suggest that disrupting the pick-up of information from the hip region can be detrimental to anticipation performance, implying there is critical information in this region.

However, it may not be the hips themselves where the critical information is emanating, but rather the relative motions or relationships between the hip region and other information sources. Some support for this notion have been provided by Piras and Vickers (2011), who reported that goalkeepers utilize a ‘visual pivot’ strategy where point of gaze is centrally located mid-way between the ball and hip region in order to enable optimal use of the fovea and parafovea. Therefore, in order to determine the role of the hip region in penalty-kick anticipation, the current experiment uses the spatial occlusion paradigm to present the hip region exclusively throughout the kick. By isolating this specific region, we can better identify how constraining access to certain information affects anticipation

performance. The temporal occlusion paradigm will also be used to identify the time-course of the involvement of the hip region as a critical cue.

Our aim in the current study was to examine the effect of expertise on response accuracy of anticipatory judgments during temporally and spatially occluded penalty kicks. Using a highly skilled sample of goalkeepers we use a novel spatial occlusion technique to isolate the role of specific cues in the successful anticipation of penalty kicks. It is hypothesized that the skilled group will perform significantly better than the less-skilled group in all conditions (cf. Mann, Williams, Ward, & Janelle, 2007). Based on previous research (Causer & Williams, 2015; Smeeton & Williams, 2012), we predict that both groups will perform significantly better in the later temporal occlusion conditions, compared to the earlier conditions. We also expect performance decrements for both groups in the spatially occluded conditions, compared to the full body condition (Diaz et al., 2012; Lopes et al., 2014; Müller, Abernethy, & Farrow, 2006).

Method

Participants

Twenty-four male soccer goalkeepers volunteered to take part in the study. Participants were divided equally into either a skilled or less-skilled group based on playing level and experience. The skilled group consisted of 12 players (mean age = 26.8, *SD* = 4.3 years) who currently played professional or semi-professional soccer and had been participating in the sport for an average of 10.8 (*SD* = 3.4) seasons. The less-skilled group included 12 players (mean age = 25.8, *SD* = 5.2 years) who had only recreational playing experience. Participants were free to withdraw from testing at any stage and approval for the study was gained via the local Ethics Committee of the lead author's institution.

Test Film

The test film was produced in conjunction with a professional soccer club in the UK. Four full-time, academy players were filmed from the goalkeeper's perspective taking penalty-kicks. The film clips were recorded using a digital video camera (Canon DM-XM2 PAL, Tokyo, Japan) positioned in the middle of the goal at eye level (1.7 m). The players were asked to take the penalty-kick using the strategy that they would use in normal competition. Two of the players were right footed and two were left footed penalty takers. A regular dimension goal was used and players were required to shoot into each of the four corners of the goal in turn. If the ball finished in the middle of the goal, the trial was discarded. Each film clip included the penalty taker's approach to the ball and all his preparatory actions until the ball was kicked. Players were required to place three penalties in each corner providing a total of 48 penalties. The players were informed that they should imagine that they were taking a penalty in a competitive match situation. The footage was then digitally edited using Adobe Premiere Pro CS4 software (Adobe Systems Incorporated, San Jose, CA) so that each clip was temporally-occluded at either the moment of ball contact, 80 ms before ball contact (-80 ms) or 160 ms before ball contact (-160 ms). A second test film was created by spatially editing the temporally-occluded clips using Mokey 4.0 (Imagineer systems Ltd, NY) to remove all of the body segments of the player, apart from the hip region (see Figure 1). The background environment replaced the areas where the body segments had been deleted; the ball was left in the clip as a reference point.

Procedure

The film clips were back projected, using a LCD video projector (Hitachi CP-X345, Yokohama, Japan) onto a 2.7 m x 3.6 m large projection screen (Draper Cinefold, Spiceland, IN). Participants stood 3.5 m away from the screen so that the film image subtended a visual angle of approximately 70º in the horizontal and 55º in the vertical direction; these angles and distances were used to match those of a live penalty kick. Participants were required to

verbalize the direction of the penalty kick (top left, top right, bottom left, bottom right), and also move as if there were trying to save the penalty kick. The movement was not recorded as a dependent variable, but used to increase the fidelity of the task. No feedback was given in relation to response accuracy. A sample of six random practice trials was shown pre-experiment for each test film to help the participants familiarize themselves with the task. After familiarization, the two test films (full body, hip region) were presented, with a 5-minute break in between; order of the test films was counterbalanced across participants. Shot presentation sequence was randomized across the conditions. Each trial lasted approximately 4 seconds, with 5 seconds between trials for the participant to response and reset for the next trial.

Insert Figure 1 here

Statistical analysis

Correct response (%) was measured by comparing the participant's response on a trial to the location the ball crossed the line. Successful performance was recorded when the participant correctly predicted both the side and height of the penalty-kick. In addition, individual analyses of the percentage of penalties where the participants correctly anticipated the height of the penalty, and separately the side of the penalty, were conducted. All dependent variables were analyzed using a 2 Group (skilled, less-skilled) x 3 Temporal Occlusion (-160 ms, -80 ms, ball contact) x 2 Spatial Occlusion (full body, hip region) mixed design ANOVA. Independent t-tests were also conducted for each condition against chance levels. Effect sizes were calculated using partial eta squared values (η_p^2). Significant effects were followed up using bonferroni corrected pair-wise comparisons. The alpha level for

significance was set at 0.05. The Greenhouse-Geisser correction was applied when violations to sphericity were observed.

Results

Correct response (%)

There was a significant main effect for group, $F_{1, 22} = 290.59$, $p < 0.001$, $\eta_p^2 = 0.98$. The skilled group recorded significantly higher accuracy scores ($M = 70$, $SD = 14$ %), compared to the less-skilled group ($M = 45$, $SD = 12$ %). There was a significant main effect for temporal occlusion, $F_{2, 44} = 209.56$, $p < 0.001$, $\eta_p^2 = 0.91$. Response accuracy was significantly higher in the ball contact ($M = 71$, $SD = 18$ %), compared to the -80 ms ($M = 56$, $SD = 14$ %; $p < 0.001$) and -160 ms ($M = 46$, $SD = 14$ %; $p < 0.001$) conditions. Response accuracy was also significantly higher in the -80 ms, compared to the -160 ms condition ($p < 0.001$). There was a significant main effect for spatial occlusion, $F_{1, 22} = 248.16$, $p < 0.001$, $\eta_p^2 = 0.92$. Response accuracy was significantly higher in the full body condition ($M = 63$, $SD = 17$ %; $p < 0.001$) compared to the hip region condition ($M = 52$, $SD = 18$ %).

There was a significant group x temporal occlusion interaction, $F_{2, 44} = 6.50$, $p = 0.003$, $\eta_p^2 = 0.23$. Both groups improved their response accuracy from the earliest occlusion point to the latest. However, while the less-skilled group increased performance incrementally by approximately 10 % in each condition, the skilled group demonstrated a more drastic increased from -80 ms to ball contact (mean difference (MD) = 19 %). There was a significant group x spatial occlusion interaction, $F_{1, 22} = 6.66$, $p = 0.017$, $\eta_p^2 = 0.23$, see Figure 3. Both skill groups performed significantly better in the full body condition, compared to the hip region condition. However, the skilled group managed to maintain

performance to a better extent (MD = 10 %) in the hip region condition, compared to the less-skilled group (MD = 13 %).

There was a significant group x temporal occlusion x spatial occlusion interaction, $F_{2, 44} = 11.63$, $p < 0.001$, $\eta_p^2 = 0.35$, see Figure 2. Both groups performed better in the later occlusion points, compared to earlier occlusion points, and in the full body condition, compared to hip region condition. However, the skilled group's response accuracy in the ball contact condition did not significantly differ between the full body and hip region condition (MD = 6 %), whereas the less-skilled group showed a significant decrease in accuracy (MD = 19 %). No other interactions were significant. All t-tests against chance were significant (all $p < .05$).

Insert Figure 2 here

Correct side (%)

There was a significant main effect for group, $F_{1, 22} = 45.988$, $p < 0.001$, $\eta_p^2 = 0.68$. The skilled group recorded significantly higher accuracy scores ($M = 85$, $SD = 11$ %), compared to the less-skilled group ($M = 67$, $SD = 14$ %). There was a significant main effect for temporal occlusion, $F_{2, 44} = 56.866$, $p < 0.001$, $\eta_p^2 = 0.72$. Response accuracy was significantly higher in the ball contact ($M = 80$, $SD = 16$ %), compared to the -80 ms ($M = 78$, $SD = 15$ %; $p < 0.001$) and -160 ms ($M = 70$, $SD = 14$ %; $p < 0.001$) conditions. Response accuracy was also significantly higher in the -80 ms, compared to the -160 ms condition ($p < 0.001$). There was a significant main effect for spatial occlusion, $F_{1, 22} = 27.555$, $p < 0.001$, $\eta_p^2 = 0.56$. Response accuracy was significantly higher in the full body

condition (M = 82, SD = 12 %; $p < 0.001$) compared to the hip region condition (M = 69, SD = 16 %).

There was a significant group x temporal occlusion x spatial occlusion interaction, $F_{2, 44} = 5.567$, $p = 0.007$, $\eta_p^2 = 0.20$, see Figure 3. Both groups performed better in the later occlusion points, compared to earlier occlusion points, and in the full body condition, compared to hip region condition. However, the performance decrement from full body to hip region for the skilled group's response accuracy in the ball contact condition was 9%, compared to 22% for the less-skilled group. Furthermore, there was no significant difference in response accuracy in the hip region condition for the less-skilled group across the three temporal occlusion conditions ($p < 0.05$). No other interactions were significant. For the less-skilled group in the -160 ms hip region conditions performance scores were not significantly different to chance ($t_{22} = 1.514$, $p = 0.14$). All other t-tests were significant (all $p < .05$).

Insert Figure 3 here

Correct height (%)

There was a significant main effect for group, $F_{1, 22} = 77.429$, $p < 0.001$, $\eta_p^2 = 0.78$. The skilled group recorded significantly higher accuracy scores (M = 74, SD = 13 %), compared to the less-skilled group (M = 59, SD = 10 %). There was a significant main effect for temporal occlusion, $F_{2, 44} = 2.919$, $p = 0.045$, $\eta_p^2 = 0.15$. Follow up analysis showed that response accuracy was significantly higher in the ball contact (M = 69, SD = 15 %) compared to the -160 ms (M = 64, SD = 12 %; $p = 0.017$) condition. There was a significant main effect for spatial occlusion, $F_{1, 22} = 41.118$, $p < 0.001$, $\eta_p^2 = 0.65$. Response accuracy was

significantly higher in the full body condition (M = 72, SD = 14 %) compared to the hip region condition (M = 61, SD = 11 %). There was a significant group x spatial occlusion interaction, $F_{1, 22} = 4.499$, $p = 0.045$, $\eta_p^2 = 0.17$. The performance decrement between the full body and hip region conditions for the less-skilled group was significantly smaller (MD = 8 %), compared to the skilled group (MD = 16 %), see Figure 4. No other interactions were significant. For the less-skilled group in the -160 ms ($t_{22} = 1.639$, $p = 0.12$) and -80 ms ($t_{22} = 1.045$, $p = 0.31$) hip region conditions performance scores were not significantly different to chance. All other t-tests were significant (all $p < .05$).

Insert Figure 4 here

Discussion

Our aim in this current study was to examine the effect of expertise on response accuracy of anticipatory judgments during temporally and spatially occluded penalty kicks. It was hypothesized that the skilled group would perform significantly better than the less-skilled group in all conditions (cf. Mann et al., 2007). Based on previous research (Causer & Williams, 2015; Smeeton & Williams, 2012), we predicted that both groups would perform significantly better in the later temporal occlusion conditions, compared to the earlier conditions. We also expected performance decrements for both groups in the spatially occluded conditions, compared to the full body condition (Müller et al., 2006).

In support of the main hypotheses, the skilled group outperformed the less-skilled group on all three dependent variables. This supports a plethora of previous research (for a review see Mann et al., 2007), and importantly, provides construct validity for the test film

and the methodology. Overall, participants performed better in the full body, compared to hip region, spatial occlusion condition. This finding supports our predictions and also previous literature demonstrating that access to more environmental information and cues can enhance performance (Müller et al., 2006). There was partial support for the temporal occlusion prediction and previous research (Farrow, Abernethy, & Jackson, 2005), as later occlusion conditions were associated with increased performance in the correct response and correct side analysis, but not for correct height. This finding may have been caused by the poor performance of both skill groups in the hip region condition across the temporal occlusion points. These data indicate that there may not be access to critical cues to determine ball height until the ball has been kicked, which aligns with previous research (Williams & Burwitz, 1993).

These data suggest that skilled goalkeepers can use information from the hip region to accurately anticipate penalty-kick direction. In contrast, less-skilled players are unable to use this isolated area to make accurate judgments. However, this does not necessarily mean that the hip region is critical to anticipation performance, or that this is necessarily the cue that the skilled goalkeepers use, as expert performers are able to extract information from several different sources. For example, experts are able to use other sources of information when the primary source is not available, which demonstrates their ability to adapt to task constraints in a given situation in order to maintain performance. This suggestion is supported by evidence to suggest that experts can extract information simultaneously from different areas of the body using a more global rather than local perceptual strategy (Huys et al., 2008, 2009).

At ball contact in the hip condition both skill groups struggled to distinguish the height of the kick, but the direction is ascertainable from this time point. In fact, both groups were poor at predicting height in the hip condition across all temporal occlusion conditions, suggesting

that there are limited cues available to predict height until after ball contact. In fact, the less-skilled group were no better than chance at predicting height in the -80 ms and -160 ms hip region conditions, which suggests they are unable to extract any critical cues for anticipation from this area, unlike the skilled players. This finding supports previous research suggesting, that the upper body, non-kicking foot, and initial ball flight are critical cues for successful height anticipation (Williams & Burwitz, 1993). This would also explain why both groups were more successful at anticipating height when these cues were present in the full body condition.

In terms of anticipating side, the skilled group was significantly more accurate compared to the less-skilled group. Specifically, the skilled group were less-effected by occlusion at ball contact, suggesting that the hips may contain useful cues at this time point to predict side. Conversely, the less-skilled group's anticipation accuracy was poor in hip condition across all temporal occlusion conditions, suggesting that they cannot use cues from the hips to predict sides, even at ball-contact. Specifically, in the -160 ms hip region condition, the less-skilled players were no better than chance at predicting side, suggesting that they are unable to extract the necessary information from the hip region for successful anticipation. These data suggest that experts are utilizing information from the hip region, rather than simply using the area as a 'visual pivot', or 'anchor point' as suggested previously (Piras & Vickers, 2011). Previously, researches have suggested that it is the relationships, presumably the relative motions between body segments and the ball, which are important when attempting to anticipate an opponent's intentions (Abernethy, Gill, Parks, & Packer, 2001; Ward, Williams, & Bennett, 2002). However, data from the current study suggests that expert athletes are able to use single sources of information, when needed, to infer upcoming opponent actions, albeit the players could have used the relative motion between the hip region and the ball.

Nevertheless, this does not mean that this is the most effective or typical method of cue utilisation.

Moreover, under normal task constraints, skilled performers pick up information in a more distributed, global and continuous manner rather than relying exclusively on the serial processing of a single or local source of information (Huys, Cañal-Bruland, Hagemann, & Williams, 2009; Huys, Smeeton, Hodges, Beek, & Williams, 2008; Smeeton, Huys, & Jacobs, 2013). Therefore, because experts are not overly reliant on one source of information, when only limited information is available, the skilled players would still be able to retain anticipation accuracy. This adaptability is likely developed over extensive deliberate practice through the development of domain-specific knowledge and an ability to use postural cue information to predict future actions (Causer & Ford, 2014).

The temporal occlusion data in the current study corroborates previous research (Causer & Williams, 2015; Smeeton & Williams, 2012), showing the evolution of cues across the movement. The traditional and robust temporal occlusion effect was present, with increase in accuracy with the later occlusion points (Farrow et al., 2005). However, it appears that at -80 before ball contact skilled athletes are able to demonstrate extremely high anticipation accuracies for side. This seems to be a critical time point for side prediction, as significantly decreases in performance have been noted when information in the hip region has been disguised (Causer & Williams, 2015). Furthermore, the angle of the hips has been showed to correlate to ball direction between 150 and 50 ms before ball contact (Diaz, Fajen, & Phillips, 2012). This would suggest that the relative importance of different cues alter throughout an action, with the accumulation of information from each of these cues critical for successful anticipatory judgments.

In summary, the current study further demonstrates the expert advantage in anticipation performance. However, it appears that despite experts typically using a global strategy to pick up cues, they are able to adapt to pick up information from a single, local region to make highly accurate predictions. Furthermore, it appears that there is enough information within the hip region to make highly accurate predictions of penalty kick direction, however, other information is needed in order to make predictions of height. These data have implications for anticipation training, as well as providing a base for further research isolating critical cues, and the evolution of cues over an action.

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Figures

Figure 1. Ball contact for the full body condition (left) and hip region condition (right).

Figure 2. Correct response (%; SD) for the skilled and less-skilled groups in the full body and hip region spatial occlusion conditions and for the -160, -80 and ball contact temporal occlusion conditions.

Figure 3. Correct side (%; SD) for the skilled and less-skilled groups in the full body and hip region spatial occlusion conditions and for the -160, -80 and ball contact temporal occlusion conditions.

Figure 4. Correct height (%; SD) for the skilled and less-skilled groups in the full body and hip region spatial occlusion conditions and for the -160, -80 and ball contact temporal occlusion conditions.