Anticipation and Situation Assessment Skills in Soccer Under Varying Degrees of Informational Constraint

Basevitch, Itay, Tenenbaum, Gershon, Filho, Edson, Razon, Selen, Boiangin, Nataniel and Ward, Paul

Anticipation and Situation Assessment Skills in Soccer Under Varying Degrees of Informational Constraint

Itay Basevitch
Sport Studies, Manhattanville College, NY, USA

Gershon Tenenbaum
B. Ivcher School of Psychology, Interdisciplinary Center, Herzliya, Israel

Edson Filho
School of Psychology, University of Central Lancashire, Preston, UK

Selen Razon
Department of Kinesiology, West Chester University, PA, USA

Nataniel Boiangin
Sport and Exercise Sciences, Barry University, FL, USA

Paul Ward
The MITRE Corporation, Washington D.C., USA*

Abstract

We tested the notion that expertise effects would be more noticeable when access to the situational information would be reduced by occluding (i.e., non-cued) or freezing (i.e., cued) the environment under temporal constraints. Using an adaptation of tasks developed by Ward et al. (2013), participants viewed video clips of attacking soccer plays frozen or occluded at three temporal points, then generated and prioritized situational options and anticipated the outcome. High-skill players anticipated outcomes more accurately, generated less task-irrelevant options and were better at prioritizing task-relevant options, than their low-skill counterparts. Anticipation scores were significantly and positively correlated with option prioritization and task-relevant options generated but not with total options generated. Counter to our prediction, larger skill-based option prioritization differences were observed when the play was frozen than occluded. These results indicate that processing environmental information depends on temporal and contextual conditions.

Keywords: option generation, anticipation, decision-making, team sports

Anticipation and Situation Assessment Skills in Soccer Under Varying Degrees of Informational Constraint

The ability to "read the game" is crucial in team sports. Expert players can anticipate upcoming moves (Gabbett, Rubinoff, Thorburn & Farrow, 2007; Ward & Williams, 2003; Williams & Davids, 1995), assess game situations (Belling, Suss, & Ward, 2015; Ward, Ericsson, & Williams, 2013), and make decisions accurately and efficiently (Vaeyens, Lenoir, Williams, Mazyn & Philippaerts, 2007). Such perceptual-cognitive skills are amongst the better predictors of skill level in sport (Mann, Williams, Ward & Janelle, 2007; Ward & Williams, 2003). However, limited scientific effort has been directed at identifying the underlying mechanisms accounting for superior anticipation in team sports. Even fewer scholars have examined the cognitive processes involved in assessing patterns of play (e.g., generating and prioritizing situational options) in team settings (Raab & Johnson, 2007; Ward, et al., 2013).

Several studies have examined skill-based differences in anticipation using a temporal occlusion method in team sports (e.g., Belling et al., 2015; Ward et al., 2013). These studies demonstrated that skill-based differences in the ability to anticipate the outcome of a pattern of play are more apparent when access to situational information is constrained (e.g., occluded earlier in the play sequence). Although researchers have examined extensively the effect of temporally constraining access to contextual information on anticipation (e.g., Jones & Miles, 1978), few, if any, researchers have examined the effect of temporally constraining access to contextual information on the situational assessment process. This is surprising, because the temporal occlusion method has been used extensively for studying anticipation. The results of these studies indicated consistent skill-based differences in anticipation performance at specific time-points of occlusion. Similarly, situation assessment is a process that changes over time as the play develops. Thus, research is warranted that examines the underlying mechanisms of advanced situation assessment skills under varying degrees of informational constraint induced by temporal occlusion (henceforth, temporal constraint). The purpose of this study was, therefore, to examine the relative differences in performance of high and low-skill male soccer players on domain-specific anticipation and situation assessment tests under varying degrees of temporal constraint.

Anticipation

Anticipation skills have been studied extensively in individual and team sport settings. A meta-analysis indicated that expert, elite, and high-level performers have superior skill at anticipating the outcome of a play earlier and with greater accuracy than novices (e.g., see Mann et al., 2007). Such skills provide a crucial advantage, especially in fast-paced sports where timing is of utmost importance, and the available time to respond is limited. Impressively, in time-pressured domains such as most team sports, this is often done intuitively - in the blink of an eye (for recent reviews, see Hoffman et al., 2014; Suss & Ward, 2015). However, few scholars have investigated the cognitive strategies that permit successful anticipation in team settings (for exceptions see Belling et al., 2015; Ward et al., 2013). Where supporting cognitive skills and/or processes have been explored, most have examined memory skills such as recall and recognition (e.g., North, Ward, Williams, & Ericsson, 2011; Williams & Davids, 1995). Although these memory skills might be important for successful performance, some of the findings suggest that they do not fully capture the underlying mechanisms supporting skilled performance or skilled anticipation (see North, et al., 2011).

Several studies have examined domain-specific anticipation skills in team sport settings (Belling et al., 2015; North, et al., 2011; Ward & Williams, 2003). Ward and Williams (2003) examined skill and age-based differences on a series of perceptual-cognitive tasks. Specifically, following a series of video clips of a developing soccer play that was stopped 120ms prior to ball contact, soccer players were asked to predict the upcoming actions. Elite players exhibited superior anticipation ability than their sub-elite counterparts. In a more recent study that examined the effect of reducing the available time to respond on decision-making, skilled soccer players were able to predict outcomes more accurately than less skilled players, irrespective of the amount of time available (Belling et al., 2015).

Situational Assessment

Situational assessment refers to a performer’s ability to generate (rather than select from explicitly presented) plausible options and prioritize those options in an integrated manner, based on expected future events and potential impact or likely threat to oneself or one’s team (Ward, et al., 2013). Recently, researchers investigated the mechanisms responsible for superior decision-making (including situational assessment), and tested predictions from different theoretical perspectives. Johnson and Raab (2003) suggested that, in these kinds of complex and dynamic sport situations where individuals are required to decide about how to respond, experts make use of a simple, fast and frugal heuristic called Take-the First (TTF). According to these authors, TTF predicts that the first option (i.e., a personal course of action) generated by skilled decision makers is better than those generated subsequently. From this perspective, generating more options, beyond the first, is generally considered an inefficient decision-making process that would likely result in poorer decision quality because decision makers end up choosing from a larger pool of lower quality options. The TTF heuristic is consistent with naturalistic observations of decision-making in the real world and the tenets of recognition-primed decision-making (RPD, see Klein, 1989). According to Klein, Wolf, Mitello and Zsambok, (1995) “people can recognize a situation as typical, thereby calling forth typical reactions without having to sift through large sets of alternatives” (p. 63). This apparently simple, albeit highly skilled behavior, is often referred to as a process of intuition.

In a study of handball players, Johnson and Raab (2003) demonstrated that players generated, on average, just over two options per trial, and the number of options generated was inversely related to the quality of the final chosen option. In a related study using a similar method, Raab and Johnson (2007) examined skill-based differences (i.e., experts, near-experts, and non-experts) in the option generation process among handball players. Although no skill-based differences in the number of options generated were observed (i.e., relatively few options, as in the previous study), the first option generated by the experts and their final chosen option was of a higher quality than near-experts and non-experts (Raab & Johnson, 2007).

Researchers in a range of complex domains, such as chess (Chabris & Hearst, 2003), soccer (Belling et al., 2015; Ward et al., 2013), law enforcement (Ward, Suss, Eccles, Williams, & Harris, 2013) and nursing (Ward, Torof, Whyte, Eccles & Harris, 2010) have observed findings that are generally consistent with the prescriptions but inconsistent with some of the predictions of TTF. That is, experts frequently generate better options first and tend to generate only very few options (especially when time pressure is present). However, generating more task-relevant situational options (when they are available in the environment) is often positively related to success and skill-level (e.g., Belling et al., 2015; Ward et al., 2013). According to contemporary (e.g., Ericsson & Kintsch, 1995) as well as recent (e.g., Hoffman et al., 2014; Ward, Gore, Hutton, Conway, & Hoffman, 2018; Ward, Schraagen, Gore, & Roth, 2019) conceptions of expertise, skilled performance in these types of domains is supported by the ability to efficiently index and encode information in a manner that allows one to engage in anticipatory thinking, predict future retrieval demands, and access task-relevant information as and when needed. The ability to engage in a more complex and analytical process of building a dynamic mental model, i.e., the moment-to-moment development of detailed cognitive representations that accurately represents the changing demands of the situational dynamics, has been noted as a hallmark of expert decision-making in numerous complex domains (e.g., Hoffman et al., 2014; Suss & Ward, 2015).

To test these notions, Ward et al. (2013) examined the relationship between the situational assessment process and anticipation in soccer. As per TTF, they predicted that more skilled participants would generate few options and better ones first. However, they predicted a positive relationship between the number of task-relevant options generated and the quality of decision-making (i.e., anticipation accuracy) and a negative correlation between task-irrelevant options and accuracy. Like the handball studies, a video simulation was used, in which action clips were shown to soccer players. However, in this study, players were asked to generate and prioritize the plausible options, or courses of action, that their opponent might take next, rather than generate the option(s) the participant themselves might take (the perspective and task used by Raab and Johnson, 2007). Based on an *a priori* task analysis, Ward et al. coded each possible option as task-relevant or -irrelevant. As predicted, the number of options generated was relatively small (< 3), and they observed a positive relationship between the number of task-relevant options and the accuracy of anticipatory decision (and a negative one with task-irrelevant options). No skill-based differences were observed in the total number of options generated; experts generated more relevant and fewer irrelevant options than novices.

Two major differences are noteworthy between the methods used by Raab and Johnson (2007) and Ward et al. (2013). Raab and Johnson (2007) permitted participants to generate options while observing the final frame of action frozen on screen for varying time periods. Ward et al. asked participants to either: (a) respond only after occlusion, then subsequently asked participants to repeat the task using a freeze frame approach similar to Raab and Johnson (Exp 2), or alternatively, (b) respond in an occluded mode on some trials and freeze frame on others (Exp 3).

Importantly, in both studies, only one temporal point of occlusion (or freeze frame) was used to examine situational assessment. Since the options available to a participant, and that a player generates and subsequently prioritizes vary as the context changes over time, it is possible that the two mechanisms tested in each of the prior studies may both support performance, albeit be context-dependent. The utility of both mechanisms has been shown to vary in other complex and dynamic domains based on changes in context and task demands (e.g., prediction versus decision- making) (Suss, Belling, & Ward, 2014; Suss & Ward, 2012). Interestingly, to the best of our knowledge, no studies have examined situation assessment under temporal constraint.

The Current Study

In the current study we adapted the methods used by Ward et al. (2013, Exp 2 & 3) to include the temporal occlusion method. Anticipation and situational assessment skills (i.e., option generation and prioritization) of male, high and low-skill soccer players were measured at three temporal occlusion points: 400ms or 200ms prior to a potential turning point in the opposing team's play, or at that point of play (i.e., henceforth, 0ms). Rather than make contrasts across occlusion conditions, our primary focus was on whether skill-based differences in anticipation and situation assessment could be observed at each condition, and whether these differences were compounded by display type. Hence, we conducted three separate analyses, one for each occlusion point, which allowed us to answer specific hypotheses (see below).

Based on the available anticipation data, we expected high-skill participants to make better anticipatory decisions than low-skill participants across display conditions and in each analysis (i.e., at each temporal point). Based on findings from Ward et al., (2013) we predicted that high-skill participants will perform better on the situational assessment task than low-skill participants (i.e., generate more task-relevant options, less task-irrelevant options, and better option prioritization of the relevant options) across both display conditions. It was less clear whether this finding would be observed in each analysis (i.e., at different time points) as to the best of our knowledge, this is the first study that examined option generation using several temporal points.

More specifically and based on the findings from Ward et al. (2013), we predicted that under the non-cued condition the amount of relevant options will decrease, the amount of irrelevant options will increase, and prioritization of options will be inferior relative to the cued-condition. We made slightly different predictions for anticipation than situation assessment. For the anticipation data, we expected to reveal a main effect only for skill, whereas for situational assessment we expected main effects for both skill and display. Furthermore, based on the findings from Ward et al. (2013) we predicted that high-skill participants will anticipate and assess the situation better than low-skill players across display conditions.

We also predicted, based on Ward et al., (2013), that anticipation would be positively correlated with the number of task-relevant options generated, negatively correlated to the number of task-irrelevant options generated, and positively correlated with the ability to prioritize options regardless of skill and display conditions at each of the three points of occlusion.

Hypotheses:

1) High-skill participants will perform better on the anticipation task compared to low-skill participants across display conditions and temporal points.
2) High-skill participants will perform better on the situational assessment task than low-skill participants across the display conditions.
3) Situational assessment scores will decrease in the non-cued condition compared to the cued-condition across skill level and temporal points.
4) There will be a positive correlation between anticipation scores and (a) number of task-relevant options generated and (b) option prioritization and a negative correlation with the number of task-irrelevant options generated, across skill and display conditions at each of the three points of occlusion.

Method

Participants

An a priori power analysis using G*Power 3 (Faul, Erdfelder, Lang, & Buchner, 2007) was performed to determine the number of participants needed for the study. Effect size was set at d = .40, α = .05, and $1\text{-}\beta$ = .80. The effect size used in the power analysis was estimated based on previous studies that utilized similar methods to examine anticipation and option generation differences between skill level groups (see Raab, & Johnson, 2007; Tenenbaum, Sar-El & Bar-Eli, 2000; Ward et al., 2013). Accordingly, to satisfy these conditions the minimum sample size required was n = 34. In total, 40 soccer players participated in the study. Participants were recruited from several universities located in the Southeastern region of the United States. Participants in the high-skill category met all the following inclusion criteria: (1) played soccer at or above collegiate level, (2) played organized soccer for at least 7 years, (3) played soccer for a total of 10 years or more. Participants in the low-skill category met all the following inclusion criteria: (1) never played soccer above high-school level, (2) played organized soccer for no more than 3 years, (3) played soccer for no more than 5 years in total (see Table 1 for descriptive statistics by group). The sample consisted of 19 high-skill ($M_{\text{age}} = 21.00$, $SD_{\text{age}} = 1.73$), and 21 low-skill players ($M_{\text{age}} = 22.14$, $SD_{\text{age}} = 3.49$).

Film and scenario design

The test film used in this study was identical to that used in Ward et al. (2013, Exp 2 & 3). The test film was comprised of video stimuli filmed during live, 11-player versus 11-player professional and semi-professional soccer matches in the UK. The camera was positioned above and behind one of the goals with attacking play progressing toward the camera and, hence filmed from a defensive perspective. A similar camera angle has been used in previous studies (see Belling et al., 2015; Johnson & Raab, 2003; Williams & Davids, 1995), and known-groups validity demonstrated. In total, 10 unique sequences of attacking soccer play were used in the test film, each lasting 10s, and ending prior to a turning point when the player with the ball either (a) passed the ball to another player, (b) took a shot on goal, or (c) retained possession while running with the ball. The end of the test film was edited to form cued/non-cued conditions that ended at different points in time (see below: *Task Conditions*)

Perceptual-cognitive tasks

After presentation of each video stimulus, participants were required to complete two simultaneous tasks: anticipation and situational assessment (see Ward et al., 2013).

Anticipation task. Each participant was asked to predict what would happen next by indicating (a) the action that would be taken by the opposing player with the ball (i.e., pass to player X, shoot at goal, or retain possession/dribble), (b) the direction of the play, and (c) if determined to be a pass, the destination / recipient of the pass (see Ward et al., 2013).

Situational assessment task. Each participant was asked to generate all plausible options (i.e., threats - from a defensive perspective) that the player with the ball might take, and that would warrant some consideration (i.e., as many options as they think are plausible). Participants were also asked to prioritize each of their highlighted options by ranking them in an order reflecting the greatest threat posed to the defense (e.g., rank 1 = highest threat; 2 = second highest threat, etc.; see Ward et al., 2013).

Instrumentation

Demographic information. A brief questionnaire was used to gather information on participants' age, number of years played in organized and recreational soccer, and the age when the participant first started to play soccer. This information was collected to ensure that participants met the criteria of the high- and low-skill level groups.

Anticipation performance. Three anticipation variables were recorded: action, direction, and destination (Ward et al., 2013). One point was assigned to each correct response. For each trial, the maximum total anticipation score (i.e., action + direction + destination) was 3, and for each condition of 10 trials, the maximum score was 30.

Situational assessment performance. The current study adopted the coaches' ranking that was used in Ward et al. (2013). Specifically, three expert soccer coaches from an English Premier League Football club served as "expert judges" by identifying and prioritizing the relevant task options for each trial. The coaches were able to view, analyze, and review the film several times, to ensure they were provided with enough time and information to identify the relevant options. The coaches' inter-rater reliability for options ranked was 90.4%. However, only options of total agreement among coaches were included. These ratings were subsequently verified by the expert data presented in Ward et al. (2013).

Two situational assessment variables were analyzed: amount of options generated (task-relevant and -irrelevant), and option prioritization. Option prioritization was calculated using a weighted point system (Ward et al., 2013). A 5-points score was assigned for identifying the highest priority, 4 points score for the second highest priority, and so on. Additionally, when an option was relevant, but not prioritized in the correct order (i.e., lower or higher than the coaches' ranking), the absolute difference between the two was deducted from the number of points allocated to the specific ranking. To standardize the scores among the trials, the total number of points for each trial was divided by the maximum number of points available. The final option prioritization value for each trial was between 0 and 1 (e.g., a score of 1 indicating a perfect match between the participant's and coaches' prioritization).

One rater scored the variables for all the participants, while another rater scored 20% of the participants (randomly selected). The two raters were given the same instructions and scored all the variables independently. Raters were not provided with any details regarding the group (e.g., skill level) and condition (e.g., display, temporal) to assure unbiased ratings (i.e., blind scoring). Inter-rater agreement was calculated for 20% of the variables that both raters scored. Percent agreement was 87.4% and inter-rater reliability using the Kappa statistic was .81, which is considered a strong agreement level (McHugh, 2012). In addition, all the option generation measures in the study were found to be reliable (Cronbach's alpha: task-relevant options - $\alpha = .90$, irrelevant options - $\alpha = .94$, option prioritization - $\alpha = .88$)

Answer sheet. The participants were provided with a replica drawing of the pitch on a standard size paper as per Ward et al. (2013). The answer sheets included information from the final frame of each specific action clip (i.e., goal posts, pitch markings / boundary lines and position of the ball) but did not include any player information (offensive or defensive players).

Participants used a pencil to mark their answers on a sheet, using “X” for offensive players, “O” for defensive players, arrows for direction of play, the letter “A” to mark the anticipated action, and numbers (e.g., 1-5) to indicate their ranking of threat posed by each option (where rank 1 = highest threat).

Task Conditions

Temporal conditions. Three temporal points were used in which the video clip terminated at a specific time prior to the turning point (i.e., 400ms, 200ms, 0ms). Participants watched the same clip three times (i.e., repeated conditions for the three temporal points). The temporal times chosen were based on previous research using similar temporal-occlusion methods that have examined anticipation skills (e.g., Ward & Williams, 2003).

Display conditions. Two display conditions were used, cued and non-cued (Ward et al., 2013). Participants watched the same clip twice (i.e., repeated conditions for the two cued conditions). In the cued condition, the last frame of the action clip was frozen and remained on the screen for 35s until the next clip started. Therefore, situational information was available throughout the task. The non-cued condition included a blank frame (that was identical to the response sheet) that appeared immediately after the last frame of the action clip and continued to be displayed on the screen until the next clip started for 35s. In the non-cued condition, participants completed the task without any detailed situational information and were required to rely on their situational representation containing their encoding of the preceding pattern of play. If participants responded in shorter time than the 35s allotted, they waited until the 35s passed prior to starting the next trial. In addition, participants were verbally cued to look up prior to the next trial to ensure they answer all trials on time. Participants viewed the conditions in a counterbalanced order and viewed the trials in both display conditions and in the three temporal conditions. Hence, in total there were six task conditions (i.e., 2 display x 3 temporal) per unique sequence of play and each participant watched a total of 60 clips (i.e., 6 task conditions X 10 unique sequences). Participants did not receive any feedback throughout and after completion of the testing procedure.

Procedure

The study was conducted in a quiet classroom using a 2.7m x 3.5m projection screen and a projector to display the video stimuli. Participants were asked to read and sign a consent form and provide demographic information prior to commencing the study. They were then provided with instructions and given two practice trials (i.e., one cued and one non-cued) to become familiar with the task (Ward et al., 2013). The familiarization video clips were not part of the 10-video clips pool; however, they were similar in difficulty level and followed the same process as the ones used in the trial video clips. The researcher then checked the answer sheet to ensure that the participants understood the task, and that the answer sheet was filled out correctly. Prior to each test trial, as per Ward et al., (2013) a pointer - a red box on a white screen used to mark the initial position of the ball - was presented to participants to direct their attention to the part of the screen were action would commence. Immediately afterwards, the video stimulus commenced followed by anticipation and situational assessment task completion. After the last video frame of action, participants had 35s to complete the respective answer sheet. Two different stimulus presentation orders (randomly assigned) for display and temporal conditions were used to counteract any order or familiarization effect across the 60 trials[1]. The time to complete the entire task was approximately 60min. Following test completion, participants were provided time to ask questions, and were debriefed about the study.

Analyses

[1] The results of the two stimulation presentations were statistically compared to ensure there were no order effects and familiarization of trials.

To test our specific hypotheses about skill level and display type at each occlusion point, we conducted three separate repeated-measures ANOVAs (i.e., one for each temporal point) for each of the dependent variables, anticipation and situational assessment. Display condition (cued, non-cued) was the within-participant factor, and Skill-level (high, low) was the between-participant factor in each analysis. In the analysis of number of options generated, task-relevant and irrelevant options were an additional within-participant factor (i.e., type of options generated). Effect size (ES) coefficients, partial eta squared and Cohen's *d* (pooled SD for independent group analyses and baseline SD for dependent group analyses as appropriate; Becker, 2000) were used to estimate the effect magnitudes where applicable. To analyze the relationship between anticipation and the situational assessment variables Pearson product-moment correlations (i.e., *r*) were computed (for each temporal point).

Results

Anticipation Accuracy

To test anticipation differences between skill-levels across display conditions, we conducted three separate repeated measure ANOVAs for each temporal point (i.e., 400ms, 200ms, and 0ms before the turning point) (see Figure 1). Results indicated that when the stimuli were occluded at 400ms prior to the critical incident, the only significant difference was between display conditions, *Wilk's* λ = .88, F (1, 38) = 5.12, p = 0.03, η_p^2 = .12. Participants were more accurate in predicting the outcome in the cued condition (M = 15.89, SE = .56) than in the non-cued condition (M = 14.53, SE = .48, d = .39). Skill-level differences were not significant, F (1, 38) = 1.99, p = 0.17, η_p^2 = .05, neither was the Skill x Display interaction, *Wilk's* λ = 1.00, F (1, 38) = .08, p = 0.78, η_p^2 < .01. Follow up analysis of simple effects for each display condition indicated non-significant skill level differences in both the cued (p = .13) and non-cued display conditions (p = .36).

At 200ms before the turning point, significant differences were only found between display conditions, *Wilk's* λ = .78, F (1, 38) = 10.54, $p < 0.01$, η_p^2 = .22. Participants anticipated the outcome more accurately in the cued condition (M = 16.53, SE = .56) than in the non-cued condition (M = 14.66, SE = .59, d = 53). Non-significant skill-level, F (1, 38) = 1.91, p = 0.18, η_p^2 = .05 and Skill x Display interaction effects emerged, *Wilk's* λ = 1.00, F (1, 38) = .01, p = 0.97, $\eta_p^2 < .01$. Follow up analysis of simple effects for each display condition indicated non-significant skill level differences in both the cued (p = .23) and non-cued display conditions (p = .25). At the turning point (0ms), there were significant differences between skill-levels, F (1, 38) = 10.63, $p < 0.01$, η_p^2 = .22. High-skill participants (M = 17.84, SE = .82) anticipated the outcome more accurately than low-skill participants (M = 14.17, SE = .78) and the effect was large (d = 1.06). However, non-significant display conditions, *Wilk's* λ = .98, F (1, 38) = .76, p = 0.39, η_p^2 = .02, and Skill x Display interaction, *Wilk's* λ = .98, F (1, 38) = .93, p = 0.34, η_p^2 = .02 emerged.. Follow up analysis of simple effects for each display condition indicated significant skill level effects in both the cued ($p < .01$) and non-cued display conditions (p = .02). In both display conditions, high-skill participants scored higher in anticipation compared to low-skill participants.

Situational Assessment: Option Generation

Results for the option generation data indicated that at 400ms prior to the turning point there were significant main effects for skill, F (1, 38) = 18.04, $p < 0.01$, η_p^2 = .32, and display, *Wilk's* λ = .62, F (1, 38) = 23.04, $p < 0.01$, η_p^2 = .38. Low-skill participants generated more options in general (M = 17.91, SE = .67) compared to high-skill participants (M = 13.80, SE =

.70, $d = 1.04$). Furthermore, participants generated more options under the cued ($M = 16.78$, $SE = .52$) than under the non-cued condition ($M = 14.93$, $SE = .52$, $d = .57$). Both effects (skill and display) were large. The Skill x Type interaction was also significant, *Wilk's* $\lambda = .33$, $F(1, 38) = 77.80$, $p < 0.01$, $\eta_p^2 = .67$. High-skill participants generated more task-relevant ($M = 16.47$, $SE = .61$) than -irrelevant options ($M = 11.13$, $SE = 1.02$, $d = 2.06$), while low-skill participants generated more task-irrelevant options ($M = 20.88$, $SE = .97$) than -relevant ones ($M = 14.93$, $SE = .58$, $d = 2.29$) (see Figure 2). Follow-up analysis of simple effects for each option type indicated a non-significant skill level effect for number of task-relevant options generated ($p = .08$). However, significant skill-level effects were noticed for task-irrelevant options ($p < .01$, $d = 2.25$); high-skill participant generated less task-irrelevant options than low-skill participants. None of the other interactions was significant (Fs < 3.5).

At 200ms before the turning point there were significant main effects for skill-level, $F(1, 38) = 20.16$, $p < 0.01$, $\eta_p^2 = .35$, display, *Wilk's* $\lambda = .41$, $F(1, 38) = 55.11$, $p < 0.01$, $\eta_p^2 = .59$, and a significant skill x type of options generated interaction, *Wilk's* $\lambda = .51$, $F(1, 38) = 36.89$, $p < 0.01$, $\eta_p^2 = .49$. Low-skill participants generated more options in general ($M = 18.44$, $SE = .71$) than high-skill participants ($M = 13.84$, $SE = .74$, $d = 1.46$), and both high and low skill participants generated more options in the cued ($M = 17.47$, $SE = .59$) than in the non-cued condition ($M = 14.82$, $SE = .49$, $d = .72$). However, high-skill participants generated more task-relevant options ($M = 15.82$, $SE = .68$) than -irrelevant ones ($M = 11.87$, $SE = 1.15$, $d = 1.37$ and low-skill participants generated more -irrelevant ($M = 21.33$, $SE = 1.09$) than -relevant options ($M = 15.55$, $SE = .64$, $d = 2.02$). Follow-up analysis of simple effects for each option type, resulted in a non-significant skill level effect for number of task-relevant options generated ($p = .78$). However, a significant skill-level effect emerged for task-irrelevant options ($p < .01$, $d =$

1.94); high-skill participant generated less -irrelevant options than low-skill participants. All the other interactions were not significant (Fs < 1).

Similar results were found at the turning point (0ms). The skill-level, F (1, 38) = 21.39, $p < 0.01$, $\eta_p^2 = .36$, display, *Wilk's* $\lambda = .71$, F (1, 38) = 15.8, $p < 0.01$, $\eta_p^2 = .29$, and Skill x Type, *Wilk's* $\lambda = .57$, F (1, 38) = 28.52, $p < 0.01$, $\eta_p^2 = .43$, effects were all significant. Low-skill participants generated more options in general (M = 17.85, SE = .67) than high-skill participants (M = 13.36, SE = .70, d = 1.50), more options were generated in the cued (M = 16.24, SE = .50) than in the non-cued condition (M = 14.96, SE = .53, d = 41). As in the previous two conditions, high-skill participants generated more task-relevant (M = 15.68, SE = .59) than -irrelevant options (M = 11.03, SE = 1.09, d = 1.86), while low-skill participants generated more task-irrelevant (M = 19.41, SE = 1.04) than -relevant options (M = 16.29, SE = .57, d = 1.22). Follow-up analysis of simple effects for each option type resulted in non-significant skill level effects for number of task-relevant options generated (p = .47). However, significant skill-level effect was evident for -irrelevant options ($p < .01$, d = 1.72); high-skill participant generated less -irrelevant options than low-skill participants. The other interactions were not significant (Fs < 3.5).

Situational Assessment: Option Prioritization

Results indicated that in the analysis at 400ms prior to the turning point, there were main effects for skill, F (1, 38) = 12.78, $p < 0.01$, $\eta_p^2 = .25$, and display conditions, *Wilk's* $\lambda = .62$, F (1, 38) = 23.22, $p < 0.01$, $\eta_p^2 = .38$. High-skill participants (M = 4.80, SE = .16) were better at prioritizing the options than low-skill participants (M = 4.01, SE = .15, d = 1.17). Furthermore, participants prioritized options better in the cued condition (M = 4.74, SE = .12) than in the non-cued one (M = 4.07, SE = .14, d = .89). The Skill x Display interaction was not significant, *Wilk's* λ = .98, F (1, 38) = .77, p = 0.39, η_p^2 = .02. Follow-up analysis of simple effects for each display condition, indicated significant skill level effects in both the cued (p = .02) and non-cued display conditions (p < .01). In both display conditions, high-skill participants had higher prioritization scores compared to low-skill participants.

At 200ms before the turning point, a significant Skill x Display interaction was observed, *Wilk's* λ = .89, F (1, 38) = 4.61, p = 0.04, η_p^2 = .11. Low-skill participants prioritized the options similarly under the cued (M = 4.45, SE = .20) and non-cued conditions (M = 4.52, SE = .27, d = 08). In contrast, high-skill participants prioritized the options better in the cued (M = 5.21, SE = .21) than in the non-cued condition (M = 4.54, SE = .28, d = 75) (see Figure 3). There were no significant differences between skill-levels, F (1, 38) = 1.51, p = 0.20, η_p^2 = .04, and display conditions, *Wilk's* λ= .93, F (1, 38) = 3.08, p = 0.09, η_p^2 = .08. Follow-up analysis of simple effects for each display condition, indicated no significant skill level effects for the non-cued condition (p = .93). However, significant skill-level effect was found for the cued-condition (p = .01); high-skill participant prioritized options better than low-skill participants.

At the turning point (0ms), there was a significant main effect for display, *Wilk's* λ = .81, F (1, 38) = 8.71, p < 0.01, η_p^2 = .19, and a significant Skill x Display interaction effect, *Wilk's* λ = .86, F (1, 38) = 6.36, p = 0.02, η_p^2 = .14. Low-skill participants prioritized the options similarly under the cued (M = 4.40, SE = .17) and non-cued conditions (M = 4.33, SE = .24, d = 09), while high-skill participants prioritized the options better in the cued (M = 5.16, SE = .18) than in the non-cued condition (M = 4.28, SE = .25 d = 1.15) (see Figure 3). The main skill effect was not significant, F (1, 38) = .17, p = 0.17, η_p^2 = .05. Follow up analysis of simple effects for each display condition indicated no significant skill level effect for the non-cued condition (p = .87).

However, significant skill-level effect was noted for the cued-condition ($p < .01$); high-skill participant prioritized options better than low-skill participants.

Relationship between Anticipation and Situational Assessment Variables

The correlation analysis indicated that, as predicted, at 400ms before the turning point, anticipation was significantly and positively correlated with option prioritization, $r = .46$, $p < .01$, and the number of task-relevant options generated, $r = .33$, $p < .01$. However, anticipation was not significantly correlated with the number of -irrelevant, $r = -.13$, $p = .23$, and total options generated, $r = .04$, $p = .70$ (see Table 5).

Likewise, and as predicted, at 200ms before the turning point, anticipation was significantly and positively correlated with option prioritization, $r = .63$, $p < .01$, and the number of task-relevant options generated, $r = .44$, $p < .01$. The correlations with the amount of -irrelevant options, $r = -.07$, $p = .54$, and total options generated were not significant, $r = .13$, $p = .23$.

As predicted, at the turning point (0ms) there was a positive and significant correlation between anticipation and option prioritization, $r = .49$, $p < .01$, and the number of relevant options generated, $r = .29$, $p < .01$. There was also a significant negative correlation with the number of task-irrelevant options generated, $r = -.25$, $p < .02$. The relationship between anticipation and total amount of options generated was not significant, $r = -.07$, $p = .56$.

Discussion

In this study we examined anticipation and situation assessment skills of high-skill and low-skill male soccer players in two display conditions (i.e., cued and non-cued) at three temporal points.

Anticipation Skills

We predicted that high-skill participants would be able to anticipate opponents' actions more accurately than low-skill participants across display conditions and temporal points. The findings indicated that at the turning point, these predictions were supported. High-skill soccer players anticipated the opponents' actions significantly more accurately than low-skill players, supporting previous research indicating that higher skilled level players are better able to make domain-specific, task-related decisions (Gabbet et al., 2007; Mann et al., 2007). Furthermore, participants anticipated the actions similarly under the cued and non-cued conditions and thus Skill by Display interaction was not evident, as expected. These results replicate the findings reported by Ward et al.'s (2013; Exp 3), where the anticipation data revealed significant main effects for skill-level but no display or interaction effects.

Contrary to our predictions, at 200ms and 400ms before the turning point, high-skill players did not anticipate the opponents' action significantly better than low-skill players in general and at each display condition. Although we refrained from comparing temporal points as it was not the aim of the study, previous findings indicated that at earlier temporal points, higher level players anticipated more accurately upcoming moves than lower level players (Ward et al., 2003). The rationale for larger skill-level differences at earlier temporal points is based on the notion that higher skill players can extract information using fewer environmental cues from their advanced domain-specific knowledge base and using more efficient search strategies (Ericsson & Roring, 2008; Mann et al., 2007; Panchuk & Vickers 2006; Williams & Burwitz, 1993).

In the current study, we chose the temporal points to align with previous studies that used the temporal occlusion method mainly in 1v1 situations in team and individual sports. However, other studies used different temporal points, such as Ward et al.'s (2013) Exp 1, which used the temporal points 120s prior to an action, 0 ms and 120 ms post action. Previous findings revealed that occlusion periods have both temporal and contextual characteristics that affect anticipation skill (Suss & Ward, 2015). Thus, it is plausible that lack of sufficient information in the observed scenarios prevented high-skill players to anticipate the action accurately at the earlier temporal points. Furthermore, it could be that the high-skill players had not yet acquired the skill to extract information from the environment when information is limited, or alternatively that the high and low skill players were more similar in experiences compared to previous studies. It is important to note that high-skill participants displayed superior anticipation skills than low-skill participants descriptively at all three temporal points. More targeted research must incorporate additional temporal and contextual points and compare athletes at varying skill levels to gain a better understanding of the underlying mechanisms and cues that mediate superior anticipation performance in team sports.

Furthermore, and contrary to our expectations, at the 200ms and 400ms turning points, there were anticipation differences attributed to the display conditions. Display conditions affected players of both skill-levels similarly. Specifically, anticipatory decisions declined when the environmental information was unavailable (i.e., non-cued display condition). Results are similar to Ward et al.'s (2103) Exp 2 in which there was a significant main effect for display condition, but no Skill by Display interaction was noted. However, in Ward et al.'s (2013) Exp 3, the display condition emerged to be non-significant. The reason for the inconsistency is not clear. In line with previous research findings, both skill-level players performed better at the cued condition when information was available for a longer time, and the players could extract more information from the environment compared to the non-cued condition (Mann et al., 2007).

Situational Assessment Skills: Option Generation

Consistent with previous research findings (and with the TTF prescriptions), relatively few total options were generated per trial (*M* = 3.15) with high-skill players generating fewer options (*M* = 2.92) than low-skill players (*M* = 3.38) (Raab & Johnson, 2007; Ward et al. 2013). As predicted, additional analyses on the relevance of options revealed that high-skill players generated more task-relevant options than -irrelevant ones, while low-skill players generated more task-irrelevant options than -relevant ones, which replicated Ward et al.'s (2013) research findings. Furthermore, although no significant differences were observed in the number of task-relevant options generated between skill-levels, high-skill participants generated less task-irrelevant options compared to low-skill participants. These results were consistent at both cued and non-cued display conditions and at all three temporal points. The results extend Ward et al.'s (2013) findings and previous research in the domain by indicating that option generation differences attributed to skill level exits at various temporal constraints in the situation assessment process. Similar to anticipation, situation assessment is a process that consists of the ability to attend and process dynamic and changing environmental information over time. Future research must examine other temporal points (e.g., 100ms after the action) to expand on the option generation process. The findings further indicate that a crucial process in option generation is the ability to distinguish among options and focus on task-relevant options; a characteristic of more experienced players (Ward et al., 2013). Furthermore, the results indicate that it is crucial to consider the type of options generated rather than the total amount of options as indicated by Raab and Johnson (2007) when evaluating and training option generation skills. In addition, the results support the notion that higher-level players maintain a more comprehensive representation of the domain-specific situation coupled with an ability to analyze the situation more efficiently; consequently, leading to more successful anticipation and decision making (Ericsson & Kintsch, 1995; Hoffman et al., 2014; Suss & Ward, 2015). The findings suggest that high-level players more than low-level players possess a better “information reduction” strategy, and that reducing the attended noise (i.e., irrelevant options) means they are better able to pay more attention to the same number of relevant options (Haider & Frensch, 1995). Lower level players on the other hand must sift through the noise to make use of the same number of relevant options.

As expected and supporting Ward et al.’s (2013) findings, participants generated more options in the cued condition than in the non-cued condition, regardless of skill-level and across temporal points. Of note, there were no differences in relevant and irrelevant options, only in total options, between display conditions. These results indicate that when more time is available to extract information from environmental cues, players tend to analyze more options in general and not necessarily more relevant options.

Situational Assessment Skills: Option Prioritization

Analyses of the option prioritization scores revealed that high-skill players were better able to indicate which options were more threatening than low-skill players at 400ms before the turning point, replicating Ward et al.’s (2013) findings. Thus, although the number of relevant options generated were similar across skill-levels, high-skill players were able to prioritize the relevant options better than low-skill players. These findings indicate that the analytic ability to prioritize options plays a major role in the perceptual-cognitive process (Ward et al., 2013). A main display effect was also observed at the 400ms temporal point. Players were able to prioritize options better in the cued condition than in the non-cued condition. These results are in-line with findings from Ward et al. (2013) and support the notion that when available, environmental information is important in the decision-making process for all skill levels.

At 200ms and 0ms before the turning point, option prioritization scores revealed a significant Skill by Display conditions interaction effect. Contrary to our predictions, a larger difference attributed to skill level was observed under the cued condition than the non-cued condition. The task and environmental constraints under this condition resembles on field situations more than the non-cued condition. However, this finding necessitates more evidence under stronger representative and ecological environments. The current study extends Ward et al.'s (2013) findings (and previous research in this domain) by exploring option prioritization differences at several temporal constraints. The results of the current study indicate that temporal constrains play a crucial role in option prioritization. Specifically, at earlier temporal points (i.e., -400ms) differences are not dependent on the display conditions, while at temporal points closer to the point of decision and action, the display conditions maintain a significant role in option prioritization of skilled players; they rely on visual information to prioritize options efficiently and when not available, their option prioritization ability decreases to a similar level of low skill players. Importantly, low skill players were not affected by the display conditions at these temporal points.

The option prioritization results contradict the predictions of the TTF heuristic stating that the first option generated should be the best option (Raab & Johnson, 2007). According to the proponents of the TTF heuristic high-skill players choose the best option first regardless of display conditions (i.e., cued and non-cued). In the current study the information available prior to generating the options was similar and thus should result in similar prioritization scores. Additionally, the findings revealed that the option generation process is analytic in nature, and not serial and intuitive. Generating options is dependent on environmental factors and constrains (e.g., time, information, score), as changes in the amount of generated options varied among the display conditions (Chabris & Hearst, 2003).

Relationship between Anticipation and Situational Assessment Variables

As predicted, a positive and significant correlation emerged between anticipation and the amount of relevant options generated and option prioritizations scores across all three temporal points. Furthermore, the amount of total options generated was not significantly correlated with anticipation at all three temporal points. Moreover, a negative and significant relationship between anticipation and the amount of irrelevant options generated at the turning point emerged (0ms). The correlations support the claims that the ability to generate and analyze plausible options is the key determinant of successful decision-making (Ward et al., 2013). Additionally, the findings indicate that the total amount of options is not related to the quality of decision-making and does not align with the predictions of the TTF heuristic that there should be a negative relation between the amount of options generated and decision-making (Raab and Johnson, 2007). An interesting finding, that replicates and extends the results from the Ward et al. (2013) study, is that option prioritization had the strongest correlation with anticipation across *the temporal points* compared to the option generation variables. This indicates that the analytic ability to process options is an imperative process in successfully anticipating upcoming events. Furthermore, the study extends previous research by indicating that the relationship between task-irrelevant options and anticipation was significant only at the turning point (i.e., just before the action). Thus, these findings indicate that it is necessary to reduce the number of irrelevant options (i.e., reducing the noise) when approaching the point of action in the decision-making process. The findings also support the notion that researchers must examine the decision making process across temporal points.

Conclusion, Limitations, and Future Research

The current study is one of the first to examine anticipation and situational assessment skills in a dynamic *team* sport setting under varying informational constraint induced by temporal occlusion. The conceptual framework and methodology used in the study was guided by Ward et al.'s (2013) study, and examined two opposing perspectives (i.e., analytical and intuitive; see Ericsson & Kintsch, 1995 and Johnson & Raab, 2003, respectively). In addition, the current study extended Ward et al.'s (2013) study (and previous studies) by exploring the situation assessment process across temporal constrains. Findings indicated that in general, high-skill players possessed more enhanced "game reading" skills than low-skill players and that display and temporal constraints determine anticipation and situation assessment processes.

Findings further indicated that anticipation and situational assessment were affected differently by display conditions depending on the temporal point. High-skill participants anticipated significantly better only at the turning point, and display conditions affected players of different skill-level similarly across temporal points. However, while results for the option generation task were similar across temporal points, high-skill players generated more relevant than irrelevant options, low-skill players generated more irrelevant options than relevant ones, and importantly, high-skill players generated less task-irrelevant option than low-skill players. Like anticipation, players of both skill-level were affected similarly by the display conditions across temporal points. Option prioritization results indicated a significant main effect for skill-level only at the 400ms temporal point. Interestingly, at the 200ms and 0ms temporal point there was a significant Display by Skill-level interaction, with larger ESs between skill levels at the cued condition. Thus, this indicates that the processes of extracting information at various temporal points and contextual situations differ among players which vary in perceptual-cognitive skills.

The relationship between anticipation and situational assessment support and extend Ward et al.'s (2013) findings and contradict the TTF heuristic predictions. The amount of options generated was not related to anticipation as expected by proponents of the TTF heuristic. However, the amount of relevant options generated and more importantly the ability to analyze those options and prioritize them was significantly and positively related to anticipation accuracy.

To capture the anticipatory and decision-making processes, more ecologically valid research methods must be employed. Specifically, methods incorporating time constraints, full body responses, and inclusion of additional environmental information such as sounds and fans, are required to fully capture the decision-making process, and the development of expertise (Belling et al., 2015; Ward et al., 2013). Brain imaging studies may further advance the understanding of space-time neural correlates underpinning skilled anticipation in sports (Nakata, Yoshie, Miura, & Kudo, 2010).

Finally, we propose that the analytical and intuitive processes complement each other; at the earlier stages of the developing play there is more uncertainty, the pattern is less structured, and more time is available compared to the latter developmental stages. Thus, skilled players may need more time under these conditions to analyze the situation, generate more options, and analytically prioritize the options (Wared et al., 2013). Conversely, just before the point of play, time is limited, and the situation is more structured and certain. Under this condition, less time is available to analyze the situation, resulting in a fast, serial, and automatic recognition-based process by the skilled players (Raab & Johnson, 2007). Consequently, a synthesis of both processes (i.e., analytical and intuitive) must be further explored.

References

Becker, L. A. (2000). Effect size. Retrieved February 16, 2019, from http: //web.uccs.edu/lbecker/Psy590/ es.htm.

Belling, P. K., Suss, J., & Ward, P. (2015). Advancing theory and application of cognitive research in sport: Using representative tasks to explain and predict skilled anticipation, decision-making, and option-generation behavior. *Psychology of Sport and Exercise*, *16*, 45-59. https://doi.org/10.1016/j.psychsport.2014.08.001

Chabris, C. F., & Hearst, E. S. (2003). Visualization, pattern recognition, and forward search: Effects of playing speed and sight of the position on grandmaster chess errors. *Cognitive Science, 27*, 637-648. https://doi.org/10.1207/s15516709cog2704_3

Eccles, D. W., & Tenenbaum, G. (2004). Why an expert team is more than a team of experts: A social-cognitive conceptualization of team coordination and communication in sport. *Journal of Sport and Exercise Psychology*, *26*(4), 542-560. https://doi.org/10.1123/jsep.26.4.542

Ericsson, K. A., & Kintsch, W. (1995). Long term working memory. *Psychological Review*, *102*, 211–245. https://doi.org/10.1037/0033-295X.102.2.211

Ericsson, K. A., & Roring, R. W. (2007). Memory as a fully integrated aspect of skilled and expert performance. *Psychology of Learning and Motivation*, *48*, 351-380. https://doi.org/10.1016/S0079-7421(07)48009-4

Faul, F., Erdfelder, E., Lang, A. G., & Buchner, A. (2007). G*power 3: A flexible statistical power analysis program for the social, behavioral, and biomedical sciences. *Behavioral Research Methods*, *39*, 175-191. https://doi.org/10.3758/BF03193146

Gabbett, T., Rubinoff, M., Thorburn, L., & Farrow, D. (2007). Testing and training anticipation skills in softball fielders. *International Journal of Sports Science & Coaching, 2*, 15-24. https://doi.org/10.1260/174795407780367159

Grehaigne, J. F., Godbout, P. P., & Bouthier, D. D. (2001). The teaching and learning of decision-making in team sports. *Quest*, *53*, 59-76. https://doi.org/10.1080/00336297.2001.10491730

Haider, H., & Frensch, P. A. (1996). The role of information reduction in skill acquisition. *Cognitive Psychology*, *30*, 304-337. https://doi.org/10.1006/cogp.1996.0009

Hoffman, R., Ward, P., Feltovich, P., DiBello, L., Fiore, S. & Andrews, D. (2014) *Accelerated expertise: Training for high proficiency in a complex world* . Psychology Press.

Johnson, J. G., & Raab, M. (2003). Take the first: Option-generation and resulting choices. *Organizational Behavior and Human Decision Processes, 91*, 215-229. https://doi.org/10.1016/S0749-5978(03)00027-X

Jones, C. M., & Miles, T. R. (1978). Use of advance cues in predicting the flight of a lawn tennis ball. *Journal of Human Movement Studies*, *4*, 231-235.

Klein, G. A. (1989). Recognition-primed decisions. In W.B. Rouse (Ed.), *Advances in man-machine systems research* (pp. 47-92). Greenwich, CT: JAI Press, Inc.

Klein, G., Wolf, S., Militello, L., & Zsambok, C. (1995). Characteristics of skilled option generation in chess. *Organizational Behavior and Human Decision Processes, 62*, 63-69. https://doi.org/10.1006/obhd.1995.1031

Mann, D. Y., Williams, A., Ward, P., & Janelle, C. M. (2007). Perceptual-Cognitive Expertise in Sport: A Meta-Analysis. *Journal of Sport and Exercise Psychology*, *29*, 457-478. https://doi.org/10.1123/jsep.29.4.457

McHugh, M. L. (2012). Interrater reliability: the kappa statistic. *Biochemia Medica*, *22*, 276-282. https://doi.org/10.11613/BM.2012.031

Nakata, H., Yoshie, M., Miura, A., & Kudo, K. (2010). Characteristics of the athletes' brain: Evidence from neurophysiology and neuroimaging. *Brain Research Reviews*, *62*, 197-211. https://doi.org/10.1016/j.humov.2006.07.001

North, J. S., Ward, P., Ericsson, A., & Williams, A. M. (2011). Mechanisms underlying skilled anticipation and recognition in a dynamic and temporally constrained domain. *Memory*, *19*, 155-168. https://doi.org/10.1080/09658211.2010.541466

Panchuk, D., & Vickers, J. N. (2006). Gaze behaviors of goaltenders under spatial–temporal constraints. *Human movement science*, *25*(6), 733-752. https://doi.org/10.1016/j.humov.2006.07.001

Raab, M., & Johnson, J. G. (2007). Expertise-based differences in search and option-generation strategies. *Journal of Experimental Psychology: Applied*, *13*, 158-170. https://doi.org/10.1037/1076-898X.13.3.158

Suss, J., Belling, P., & Ward, P., (2014). Use of cognitive task analysis to probe option generation in law enforcement. *Proceedings of the Human Factors and Ergonomics Society 58th Annual Meeting,* Chicago, IL. 58, pp. 280-284. https://doi.org/10.1177/1541931214581058

Suss, J., & Ward, P**.** (2012). Use of an option generation paradigm to investigate situation assessment and response selection in law enforcement. *Proceedings of the Human Factors and Ergonomics Society 56th Annual Meeting,* Boston, MA. October 22-26, 2012. Santa Monica, HFES. https://doi.org/10.1177/1071181312561069

Suss, J. and Ward, P. (2015). Predicting the future in perceptual-motor domains: perceptual anticipation, option generation and expertise. In*: The Cambridge Handbook of Applied Perception Research*. Cambridge University Press. pp. 951-976. https://doi.org/10.1017/CBO9780511973017.056

Tenenbaum, G., Sar-El, T., & Bar-Eli, M. (2000). Anticipation of ball location in low and high-skill performers: A developmental perspective. *Psychology of Sport and Exercise, 1*, 117-128. https://doi.org/10.1016/S1469-0292(00)00008-X

Vaeyens, R., Lenoir, M., Williams, A. M., Mazyn, L., & Philippaerts, R. M. (2007). The effects of task constraints on visual search behavior and decision-making skill in youth soccer players. *Journal of Sport and Exercise Psychology, 29*, 147-169. https://doi.org/10.1123/jsep.29.2.147

Ward, P., Ericsson, K. A., & Williams, A. M., (2013). Complex perceptual cognitive expertise in a simulated task environment. *Journal of Cognitive Engineering and Decision-making, 7*, 231-254. https://doi.org/10.1177/1555343412461254

Ward, P., Gore, J., Hutton, R., Conway, G., & Hoffman, R. (2018). Adaptive skill as the *conditio sine qua non* of expertise. *Journal of Applied Research in Memory and Cognition, 7*, 35-50. doi: 10.3389/fpsyg.2017.00515

Ward, P, Hoffman, R. R., Conway, G., Schraagen, J. M., Peebles, D, Hutton, R. J. & Petushek, E. J. (2017). Editorial: Macrocognition: The science and engineering of sociotechnical work systems. *Frontiers in Psychology*, 8(515). https://doi.org/10.3389/fpsyg.2017.00515

Ward, P., Schraagen, J. M., Gore, J., & Roth, E. (Eds.) (2019). *The Oxford handbook of expertise:* Oxford, UK: Oxford University Press. https://doi.org/10.1093/oxfordhb/9780198795872.001.0001

Ward, P., Suss, J., Eccles, D. W., Williams, A. M., & Harris, K. R. (2011). Skill-based differences in option generation in a complex task: A verbal protocol analysis. *Cognitive processing*, *12*(3), 289-300. https://doi.org/10.1007/s10339-011-0397-9

Ward, P., Torof, J., Whyte, J., Eccles, D. W., & Harris, K. R. (2010). Option generation and decision-making in critical-care nursing. Paper presented at the 54th Annual Meeting of the Human Factors and Ergonomics Society, San Francisco, CA. https://doi.org/10.1177/154193121005400418

Ward, P., & Williams, A. M. (2003). Perceptual and cognitive skill development in soccer: The multidimensional nature of expert performance. *Journal of Sport and Exercise Psychology*, *25*, 93-111. https://doi.org/10.1123/jsep.25.1.93

Williams, A. M., & Burwitz, L. (1993). Advance cue utilization in soccer. In T. Reilly, J. Clarys, & A. Stibbe (Eds.), *Science and football* (Vol II, pp. 239–244). London: E & FN Spon.

Williams, M., & Davids, K. (1995). Declarative knowledge in sport: A by-product of experience or a characteristic of expertise? *Journal of Sport and Exercise Psychology*, *17*, 259-275. https://doi.org/10.1123/jsep.17.3.259

Williams, A. M., & Ward, P. (2007). Perceptual-cognitive expertise in sport: Exploring new horizons. In G. Tenenbaum, & R. C. Eklund (Eds.), *Handbook of Sport Psychology* (pp. 203–223). New York: John Wiley and Sons.

Table Captions

Table 1

Descriptive statistics (i.e., M and SD) for experience playing soccer by skill level.

Skill	Organized Soccer	General Soccer	Age Started
Low (*n* = 21)	1.00(1.14)	2.21(1.74)	8.74(4.96)
High (*n* =19)	13.79(4.33)	16.11(2.85)	4.79(2.45)

Table 2

Correlations between anticipation and situational assessment at all three temporal points

Situational Assessment	Anticipation (0ms)	Anticipation (200ms)	Anticipation (400ms)
Option prioritization	.49**	.63**	.46**
Task-relevant options	.29**	.44**	.33**
Task-irrelevant options	-.25*	-.07	-.13
Total options	-.07	.13	.04

*$p < .05$. **$p < .01$

Figure Captions

Figure 1. Anticipation scores (*M* and *SD*) by skill, display, and temporal conditions.

Figure 2. Task-relevant and task-irrelevant options generated (*M* and *SD*) by skill, display, and temporal conditions.

Figure 3. Option prioritization scores (*M* and *SD*) by skill, display, and temporal conditions.