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The impact of contextual information and a secondary task on anticipation performance: An interpretation using Cognitive Load Theory

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Abstract

When performing under severe time constraints, sports performers use kinematic and contextual information to facilitate anticipation. We examined the relative importance of these two information sources and their impact on cognitive load and anticipation performance. Cognitive Load Theory (CLT) predicts that adding more information sources to a task will increase cognitive load in less-skilled but not skilled performers. Skilled and less-skilled cricket batters anticipated deliveries from bowlers on a life-size screen under four conditions that manipulated access to contextual information and included a secondary task. The presence of context enhanced anticipation accuracy for both skilled and less-skilled groups, without affecting cognitive load. Skilled performers used sequencing and game-related contextual information in addition to kinematic information to facilitate anticipation, while both groups reported using information pertaining to opponent positioning. Findings highlight the importance of context in anticipation and suggest that the addition of context may not necessarily negatively impact cognitive load.

The impact of contextual information and a secondary task on anticipation performance: An interpretation using Cognitive Load Theory

In domains in which performers are required to make decisions and perform actions under severe time pressure (e.g., sport and military combat environments), the ability to accurately anticipate what an opponent will do in a given situation is crucial (Abernethy & Wollstein, 1989; Mann, Williams, Ward, & Janelle, 2007; Murphy et al., 2016; Williams, 2009). For example, tasks such as striking a fastball in baseball, which involve processing times of less than half a second with small margins for error, would be near impossible to execute without the ability to anticipate (Gray, 2002). The superior ability of skilled performers to anticipate is underpinned by the use of information from at least two broad sources, namely, the pick-up of low-level biological motion information from an opponent's movement kinematics (i.e., postural cues) and the use of high-level contextual information (Müller & Abernethy, 2012).

In their two-stage model, Müller and Abernethy (2012) propose that skilled performers use these contextual and kinematic sources of information to initially guide early positioning of the lower body (such as the foot movement in cricket batting) and movement responses are then fine-tuned using information from ball flight (such as manipulating the face of the bat). Research underpinning the first stage of the model has mainly focused on identifying how, what, and when performers pick-up kinematic sources of information. An extensive body of evidence exists to suggest that skilled athletes are able to use kinematic information from opponents' movements in order to make accurate anticipation judgments (Abernethy & Zawi, 2007; Müller, Abernethy, & Farrow, 2006; Williams & Davids, 1998). For example, using a temporal occlusion approach, Müller et al. (2006) demonstrated that skilled cricket batters process advanced postural cues to better anticipate the delivery of an opponent than their less-skilled counterparts. However, the pick-up of postural cues is not the only source of information underpinning skilled anticipation (Loffing & Cañal-Bruland, 2017; Müller & Abernethy, 2012).

Roca, Ford, McRobert, and Williams (2013) showed that multiple processes underpin skilled anticipation, not only the pick-up of visual kinematic information in the form of postural cues and pattern recognition, but also the use of situational probabilities which arise from the use of contextual information. More recently, Murphy et al. (2016) used a novel approach to compare how tennis players made anticipation judgments when viewing rallies presented as normal video and animated footage in which postural information was removed. These authors demonstrated that both kinematic and contextual information contribute to anticipation and that effective processing of contextual information is a strong predictor of expert performance.

While Müller and Abernethy (2012) acknowledge the potential importance of early information in striking sports, the model outlines the limited scope of empirical evidence concerning the use of contextual information sources such as the game situation. This omission in the literature is notable and it was highlighted again by Cañal-Bruland and Mann (2015) who identified three areas that require investigation in order to develop a clearer picture of the role of context in skilled anticipation. First, research is needed to identify the specific sources of contextual information employed. Second, research is needed to examine how the different sources of contextual information interact with the pick-up of biological motion information. Third, research is need to develop a clearer picture of how the specific situation and circumstances shape the use of contextual information. Furthermore, only a few researchers have explored how multiple sources of contextual information may interact to facilitate anticipation and, importantly, how they combine with the availability of kinematic information (Morris-Binelli & Müller, 2017; Roca & Williams, 2016).

In investigating context, researchers have applied the term to describe a variety of information sources. Runswick, Roca, Williams, Bezodis, and North (2017) differentiate between *situation-specific* and *non situation-specific* contextual information. The former relates to information sources that are changeable and unique to that specific event, such as game score and opponent positions, whereas the latter pertains to those that are more stable, such as a team's past performances and playing style. In this paper, we focus on the situation-specific sources of contextual information that can be readily manipulated and applied to experimental designs and learning environments. Several researchers have identified pertinent sources of situation-specific contextual information. For example, knowledge of game score (Farrow & Reid, 2012), the sequence in which information is displayed (McRobert, Ward, Eccles, & Williams, 2011), knowledge of opponent position (Loffing & Hagemann, 2014), and information concerning positioning of both opposing players and team-mates (Paull & Glencross, 1997), have been shown to enhance the ability to anticipate. Runswick et al. (2017) manipulated multiple sources of situation-specific contextual information while skilled cricket batsmen faced a bowler in-situ. The results showed that adding multiple sources of context to a complex task affected movement execution but did not affect the levels of mental effort invested by skilled performers. This latter finding can be interpreted using Cognitive Load Theory (CLT; de Jong, 2010; Sweller, 1988; 1994; Van Merriënboer & Sweller, 2005).

The CLT is a well-established theory of instructional design that originates from problem solving tasks in educational psychology. The theory assumes that the capacity of working memory is limited and the cognitive load associated with a task determines how much of this capacity is used. Cognitive load is created in three ways, intrinsic, extraneous, and germane load, each with specific implications for optimizing task design (Moreno & Park, 2010). The intrinsic load refers to the difficulty of the task itself and depends on the prior knowledge of the learner (Sweller, 1994). The extraneous cognitive load refers to the way an instructional task is presented (Sweller, Chandler, Tierney, & Cooper, 1990). Germane load (Sweller, van Merriënboer, & Paas, 1998) consists of the cognitive resources devoted to schema acquisition and automization (the development of specific cognitive representations to automatically process information). These three sources are additive, and they combine to create the total cognitive load. An increase in intrinsic and extraneous load can negatively affect learning due to a lack of available memory capacity for germane load and the building and modifying schemata.

If the total load becomes excessive, performance on the task can be negatively affected (Paas, Renkle, & Sweller, 2003).

The expertise reversal effect (Kalyuga, Ayres, Chandler, & Sweller, 2003) suggests that the predictions of CLT, such as increasing the complexity of a task causing an increase in cognitive load, do not hold for more experienced performers like those tested by Runswick et al. (2017). The suggestion is that experienced performers can automatically integrate extra task-relevant information using existing schemata without any impact on cognitive load. Presenting a task in a more complex manner would not increase extraneous load for experienced performers, whereas it would for those with less experience who do not have existing schemata to integrate task-relevant information automatically. Initially, work with CLT focused on reducing extraneous load in inexperienced learners using classroom tasks (e.g., Sweller, 1988), but subsequently its application has been extended to other domains which contain a number of sources of task-relevant information and to more skilled learners. For example, CLT has been applied to training in medicine and to human factors (e.g., Engström, Markkula, Victor, & Merat, 2017; Leppink & Duvivier, 2016; Young, van Merriënboer, Durning, & Ten Cate, 2014). de Jong (2010) suggested that CLT should apply to highly complex tasks for which learners must use all available resources to make decisions in a very short time (e.g., flying a plane). However, CLT and the expertise reversal effect have not been applied to understanding the execution of temporally-constrained interceptive actions in skilled or less-skilled performers.

The CLT has usually made assumptions about the effect of increasing cognitive load on learning, but the effect that cognitive load has on performing the primary task can also be important. Other theories based on a limited capacity working memory that investigate anxiety, such as attentional control theory (Eysenck, Derakshan, Santos, & Calvo, 2007), have extensively investigated working-memory capacity and performance under anxiety. However, few researchers have investigated how other sources of load, such as those outlined in

CLT affect performance. In vehicle driving tasks, it has been shown that increased cognitive load has a negative effect on aspects of driving performance requiring cognitive control (Engström et al., 2017) and that changes can result in modifications to visual attention (Lee, Lee, & Boyle, 2007). However, the addition of information that is relevant to the primary task (e.g., contextual information) has not been investigated in complex, time-constrained skills. While researchers investigating CLT have focused on simple tasks with less-skilled performers, investigations into context and anticipation have primarily focused on skilled performers. No attention has been focused on whether less-skilled performers can use and integrate contextual and kinematic information sources to develop anticipation (Morris-Binelli & Müller, 2017; Müller & Abernethy, 2012). The application of CLT to investigate cognitive load, context, and anticipation performance in a study utilizing skilled and less-skilled groups offers an opportunity to address these shortcomings in the literature.

Performance on a secondary task has been suggested as a useful method for assessing the attentional load placed on a performer (de Jong, 2010; Ellmers, Cocks, Doumas, Williams, & Young, 2016). Since the secondary task is not relevant to the primary task, no existing schemata would exist for any skill level and the secondary task should add load. According to CLT, the effect of adding too much contextual information would increase extraneous load in less-skilled performers in a similar fashion to an unrelated secondary task. In experienced performers, however, this would not be the case because contextual information could be automatically processed through existing schemata. If the addition of contextual information causes excessive cognitive load in less-skilled performers, identifying which information sources are most important in skilled anticipation can guide the application of CLT in a new domain, ensuring that only key information is presented during practice and that working memory is not overloaded.

In this paper, we examine the effect of contextual information on anticipation performance and explore the relative importance of kinematic and contextual information, as well as how these two sources of information interact to facilitate anticipation. We use a video-based anticipation task involving cricket and manipulate access to contextual information while introducing a secondary task to examine the effects of context on anticipation performance and cognitive load in skilled and less-skilled performers. Furthermore, we build on previous literature that has identified the sources of contextual information that aid anticipation by including a variety of these sources in the experimental design, allowing for the investigation of how different sources are used during the anticipation process. We predicted, based on CLT and Müller and Abernethy's (2012) model of anticipation in striking sports, that the addition of context would improve anticipation accuracy in skilled performers. In contrast, we predicted that the presence of context would reduce anticipation accuracy in less-skilled performers, who would not be able to automatically integrate contextual information without greatly increasing cognitive load. Furthermore, we hypothesized that context would cause increased cognitive load and negatively affect performance on both primary and secondary tasks in the less-skilled group. We also predicted that both skilled and less-skilled groups would show a reduction in anticipation accuracy under secondary task conditions because of the increase in cognitive load due to the lack of access to task-specific schemata to automatically integrate non-task relevant information.

Method

Participants

In order to test predictions of CLT, a comparison between less-skilled participants and performers who have had the opportunity to develop schemata through exposure to match-play context was required. Therefore, nine skilled male cricket batsmen (M age = 22.6 ± 7.8 years) who played at a minimum of club first team level (M experience = 13.6 ± 6.3 years) and nine less-skilled male participants (M age = 28.9± 6.7 years) with no competitive cricket experience volunteered to participate. Five of the skilled players had experience at county level and one at international level. Although the less-skilled participants had no experience of playing in a cricket match, they all resided in a cricket-playing nation and therefore could have experienced exposure to non-competitive cricket in a physical education context. As a result, this group were labelled as less-skilled rather than novice. The research was conducted in accordance with the ethical guidelines of the lead institution and written informed consent was obtained from all participants at the outset.

Dependent Measures

Anticipation Performance. Participants viewed occluded clips of cricket bowlers and were asked to predict the point the ball would have passed the stumps, marking this on diagrams scaled down to 8 × smaller than game size to fit a single A4 sheet. The radial error from correct ball location was measured and scaled back up to quantify anticipation accuracy at game scale (i.e., how far the bat would have been from the ball). Trials repeated across both conditions were used for analysis to negate any effect of variations in trial difficulty. To improve engagement with the task, participants were asked to play the appropriate shot to hit or leave the ball at the time they thought the ball would have passed them (as per instructions used by McRobert, Williams, Ward, and Eccles, 2009; McRobert et al., 2011). Deciding whether to play at a delivery or 'leave' (not play a shot at the ball) is a key skill in cricket batting. Skilled batsmen need to be able to accurately decide where the ball will pass stumps and whether it is likely to hit the stumps if it is not intercepted.

Secondary Task Performance. Secondary task performance was defined as the number of correct responses verbalized. The number of correct responses per second in both single and dual-task counting was calculated to negate any effect of difference in trial length. The participants' ability to perform the secondary counting task concurrently to the primary task, both with and without context, was quantified by using the dual-task cost (DTC) formula, DTC (%) = 100 (single-task score – dual-task score) / single-task score (Ellmers et al., 2016; McDowd, 1986). The higher the dual-task cost, the poorer the counting performance when performed alongside the primary anticipation task compared with when performed in isolation.

Mental Effort. The Rating Scale for Mental Effort (RSME) was used to assess how context and a secondary task affected mental effort. It is a one-dimensional linear scale which runs from 0-150 with zero corresponding to not at all effortful, 75 corresponding to moderately effortful, and 150 to very effortful. The scale has been reported as a valid and reliable measure of mental effort (see Veltman & Gaillard, 1996). Scores from the RSME were collected on six occasions in each condition and always after a repeated trial to allow for direct repeated measures comparison between control and context.

Verbal Reports. Retrospective verbal reports were collected on six occasions in each condition. These were always collected after a repeated trial to allow for direct comparison of the same trials across conditions. Participants were not required to include numbers from the secondary counting task in reports. Verbal reports were transcribed verbatim and coded into two sets of four categories. First, statements were coded into cognitive categories based on the structure outlined by Ericsson and Simon (1993), and developed by Ward, Williams, and Ericsson (2003), that has been used previously to investigate mechanisms underpinning anticipation (McRobert et al., 2011; Murphy et al., 2016; North, Ward, Ericsson, & Williams, 2011; Roca, Ford, McRobert, & Williams, 2011). Cognitive categories included: (i) *monitoring statements*, recalling descriptions of current events and current actions; (ii) *planning*, referring to potential decisions on a course of action to anticipate an outcome event; (iii) *predictions*, referring to statements anticipating or highlighting possible future events; and (iv) *evaluations,* referring to statements making some form of comparison, assessment or appraisal of events that are situation-, task-, or context-relevant. Second, reports were coded into categories based on the sources of information. Categories based on previously discussed information sources included: (i) *kinematic*, statements that mention cues from the bowler's body (McRobert et al., 2011); (ii) *sequencing*, statements that mention events of previous deliveries or actions (McRobert et al., 2011); (iii) *game situation*, statements that mention the score or time left in the game (Farrow & Reid, 2012; Paull & Glencross, 1997); and (iv) *field positioning*, statements that mention the position of the opposition fielders (Loffing & Hagemann, 2014; Paull & Glencross, 1997).

Procedure

We used the same stimuli as previously employed by McRobert et al. (2009). Ten (M age = 19.5 ± 2.5 years) county-level cricket bowlers (six fast; four spin) were recruited to create the video-based test stimuli. A camera was positioned on the batting crease at a height of 1.7 m and in line with middle stump so that it represented a typical viewing perspective while batting. The different bowlers were recorded delivering a full over (six deliveries) as they would in a game situation, yielding 60 unique deliveries. Footage was occluded immediately prior to ball release, focusing on the first stage of Müller and Abernethy's (2012) model in which situational probabilities are used. Clips were divided into two blocks of 36 deliveries (12 deliveries were repeated in the two conditions to allow for direct repeated measures comparison).

To ensure there was no context displayed in the control condition, footage showed only the bowler with no further contextual information and no two deliveries from the same bowler were displayed consecutively. The sequencing of information in cricket has been identified as an important source of context (McRobert et al., 2011). The context condition showed sequences of six deliveries from the same bowler (as would be seen in a match) and included information about field settings and game situation**.** A panel of three independent qualified cricket coaches viewed the full non-occluded footage and agreed upon a game situation and field that would be tactically appropriate for the location of the deliveries in each over in order to maintain congruence between visual and contextual information and avoid any element of deception in the presentation of context. Participants received information on the game score, including the number of overs bowled, runs scored and wickets taken prior to seeing the delivery (i.e. as if looking at a scoreboard) and were informed that the format was a one-day international (50 over) match. The field settings were displayed on a schematic representation prior to seeing the bowler, and a matching field layout was established using cones around the participant so that field information was available throughout the delivery (see Runswick et al., 2017).

In half of the trials in the control and context conditions, participants performed a secondary task of counting backwards in multiples of seven from a random number between 100 and 200. In dual-task conditions, participants were given the random number immediately at the start of the trial and were instructed to continue counting backwards in sevens until the clip occluded. All trials that were repeated across the two main conditions had matching dual-task conditions allowing for direct comparison of the effects of context (six involved a secondary task and six did not). The footage was displayed on a life-size screen, projected from the side using a horizontal keystone projector (Epson-X31, Japan). A regulation size batting crease and stumps were placed in front of the screen to allow participants to bat against the bowlers in a realistic fashion. Conditions were counterbalanced to negate ordering effects.

Participants recorded a 30-second baseline measure for backwards counting which involved sitting down and counting backwards in sevens from 150 for 30 seconds (Ellmers et al., 2016) and underwent training in providing verbal reports using Ericsson and Kirk's (2001) adaptation of Ericsson and Simon's (1993) original protocol. Training included instruction on thinking aloud and giving immediate retrospective verbal reports by solving a range of generic and domain-specific tasks (see Eccles, 2012). The verbal report training protocol lasted approximately 30 minutes. Participants were informed how to use the RSME (Zijlstra, 1993) and response sheets, and were given a regulation size cricket bat and asked to stand in front of the stumps to face a familiarization trial for both conditions. Participants were asked to practice giving retrospective verbal reports during the familiarization trials. If these reports were not satisfactory due to the tendency of participants to summarize or explain their thought processes, the participant was reminded of the training he had received and further practice attempts provided. Less-skilled players were given no instruction on how to bat. However, they were informed that in cricket the bowler can bowl a legal delivery anywhere between the wide lines marked on the crease, the ball does not have to be aimed at the stumps and can bounce once before reaching the batter (unlike pitching over the plate in baseball).

Data Analysis

Separate three-way mixed design ANOVAs were used to analyze the effect of group, context, and dual-task on each measure respectively. A separate four-way mixed design ANOVA including statement type was used to analyze each set of verbal reports. A Bonferroni adjustment was employed when multiple comparisons were being made in order to lower the significance threshold and avoid Type I errors (McLauglin & Sainani, 2014). Violations of sphericity were corrected for by adjusting the degrees of freedom using the Greenhouse Geisser correction when epsilon was less than 0.75 and the Huynh-Feldt correction when greater than 0.75 (Girden, 1992). A priori power analysis was conducted using G*power (Faul, Erdfelder, Lang, & Buchner, 2007). We based our calculations on the main effect sizes for anticipation accuracy reported by McRobert et al. (2011) who used the same task and groups across two context conditions and using the within-factor effect size ($\eta_p^2 = 0.49$), a moderate correlation (r = 0.3) and power of 0.8, the total sample size required was $n = 6$. Partial eta squared (η_p^2) was used as a measure of effect size for all analyses. The alpha level (p) for statistical significance was set at 0.05.

Results

Anticipation Accuracy

The skilled group ($M_{\text{radial error}} \pm SD$; 36.6 ± 1.4 cm) showed more accurate anticipation than the less-skilled group (42.9 ± 5.4 cm; $F_{1, 16} = 10.2$, $p = 0.01$, $\eta_p^2 = 0.39$). Both skilled (control 37.7 ± 2.4 cm, context 35.5 ± 2.2 cm) and less-skilled (control 45.1 ± 6.6 cm, context 40.6 ± 4.8 cm) groups anticipated significantly more accurately with context than without (Figure 1: $F_{1, 16} = 11.82$, $p < 0.01$, $\eta_p^2 = 0.43$). Both skilled (NoDT 42.8 ± 2.1 cm, DT 30.4 ± 2.1 cm) and less-skilled (NoDT 46.6 ± 5.4 cm, DT 39.1 ± 7.3 cm) groups anticipated more accurately in dual-task conditions ($F_{1, 16} = 79.46$, $p < 0.01$, $\eta_p^2 = 0.83$). There was a significant group × dual-task interaction ($F_{1, 16} = 4.79$, $p = 0.04$, $\eta_p^2 = 0.23$). Dual-task conditions were more beneficial for anticipation accuracy in the skilled group than the less-skilled group. There was a significant context × dual-task interaction. The greatest positive effect on anticipation accuracy occurred when context was coupled with the secondary task ($F_{1, 16}$ = 13.27, p = 0.02, η_p^2 = 0.45). No group × context interaction and no three-way interaction between group × context × dual-task were found ($F \leq 3.05$, $p > 0.05$).

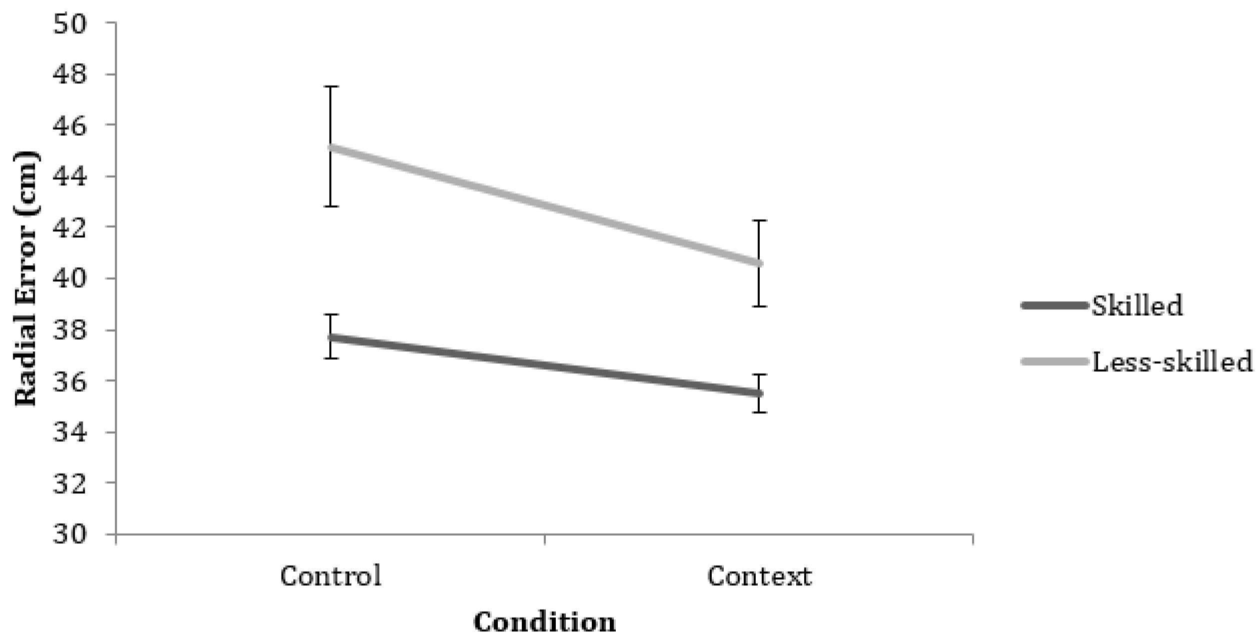

Figure 1. The anticipation scores measured in radial error for skilled and less-skilled performers with and without context (with SE bars).

Cognitive Load

RSME. There was no difference in mental effort scores between groups ($M_{score} \pm SD$; skilled 67.31 ± 17.09; less-skilled 55.25 ± 12.90, $F_{1, 16}$ = 2.84, p = 0.11, η_p^2 = 0.15**)**. The addition of context had no effect on mental effort scores in the skilled (control 66.98 ± 15.46; context 68.09 ± 17.76) or the less-skilled group (control 53.96 ± 14.20; context 56.56 ±14.28, $F_{1, 16}$ = 0.39, p = 0.54, η_p^2 = 0.02). However, mental effort scores were significantly higher with backwards counting (71.74 ± 14.17) than without (50.83 ± 17.64, $F_{1, 16} = 58.41$, $p < 0.01$, $\eta_p^2 = 0.79$). No interactions were reported (all $F \leq 3.05$, all $p > 0.05$).

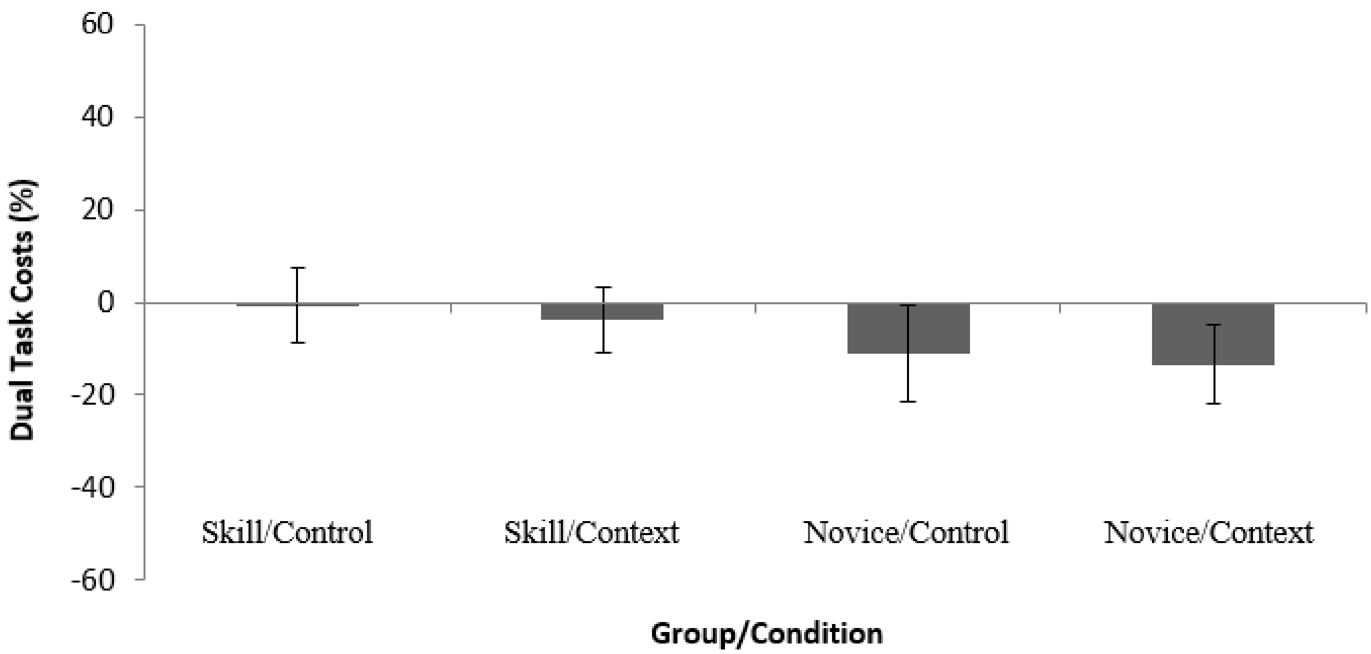

Figure 2. The dual task costs for skilled and less-skilled performers with and without context (with SE bars).

Secondary Task Performance. The two groups showed no significant differences in counting performance across the dual-task conditions (Figure 2). There was no effect of group ($M_{\text{DTC}} \pm SD$; skilled -2.21 ± 19.41%; less-skilled -12.25 ± 25.16%, $F_{1, 16} = 0.80$, $p = 0.39$, $\eta_p^2 = 0.05$) on DTC. There was also no effect of context on DTC for the skilled (control -0.69 ± 24.39%; context -3.72 ± 21.10%) or less-skilled groups (control -11.04 ± 30.98%, context -13.45 ± 25.19%; $F_{1, 16} = 0.37$, $p = 0.55$, $\eta_p^2 = 0.02$) and no significant interactions (all $F \leq 3.05$, all $p > 0.05$).

Verbal Reports

Cognitive: There was no effect of group on the number of statements reported ($M_{\text{statements per trial}} \pm SD$; skilled 6.2 ± 1.9, less-skilled 5.0 ± 1.8, $F_{1, 16} = 1.8$, $p = 0.20$, $\eta_p^2 = 0.10$). The addition of context significantly increased the number of statements reported (Figure 3; control 5.1 ± 0.4, context 6.1 ± 0.5; $F_{1, 16} = 9.96$, $p < 0.01$, $\eta_p^2 = 0.38$). There was a significant effect of statement type ($F_{3, 14} = 17.30$, $p < 0.01$, $\eta_p^2 = 0.52$) and a significant context × statement type interaction showing a decrease in monitoring statements and increase in all other types in the presence of context ($F_{3, 14} = 9.60$, $p < 0.01$, $\eta_p^2 = 0.38$). There was a significant statement type × group interaction ($F_{3, 14} = 5.03$, $p < 0.01$, $\eta_p^2 = 0.24$). The skilled group reported more planning (skilled 1.3 ± 0.9, less-skilled 0.4 ± 0.5), prediction (skilled 1.6 ± 0.7, less-skilled 1.2 ± 0.9) and evaluation statements (skilled 1.3 ± 0.4, less-skilled 0.6 ± 0.47), while the less-skilled group relied on monitoring (skilled 2.0 ± 1.1, less-skilled 2.8 ± 0.8). There was a significant three-way interaction between group × context × statement type ($F_{3, 14} = 3.81$, $p = 0.02$, $\eta_p^2 = 0.19$). While skilled performers showed a decrease in monitoring statements (control 2.4 ± 1.4, context 1.6 ± 1.1) and an increase in planning (control 0.9 ± 0.7, context 1.7 ± 1.3) and evaluation (control 0.6 ± 0.3, context 1.9 ± 0.7) due to context, participants in the less-skilled group only showed a small increase in prediction statements with context (control 1.1 ± 0.8, context 1.2 ± 1.1). There was no effect of secondary task on cognitive verbal reports (all $F \leq 3.05$, all $p > 0.05$).

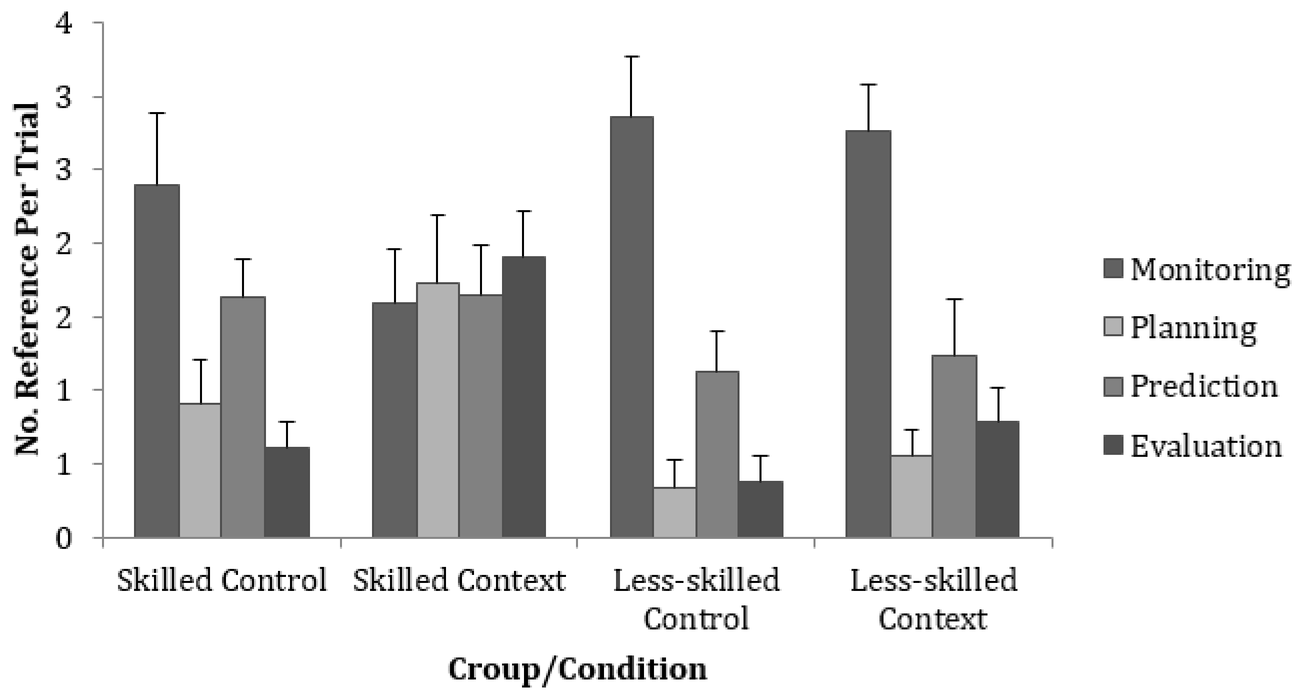

Figure 3. Verbal report statements relating to cognitive categories used by each group in context and control conditions (with SE bars).

Information Sources: There was no effect of group on the number of statements reported ($M_{\text{statements per trial}} \pm SD$; skilled 3.4 ± 1.6, less-skilled 3.1 ± 1.3, $F_{1, 16} = 0.25$, $p = 0.63$, $\eta_p^2 = 0.02$). The addition of context significantly increased the number of statements reported (control 2.8 ± 1.4, context 3.7 ± 1.7; $F_{1, 16} = 9.58$, $p = 0.01$, $\eta_p^2 = 0.37$). There was a significant effect of statement type ($F_{3, 14} = 41.92$, $p > 0.01$, $\eta_p^2 = 0.72$) and a significant context × statement type interaction showing a decrease in kinematic statements and increase in all other information sources in the presence of context ($F_{3, 14} = 15.61$, $p < 0.01$, $\eta_p^2 = 0.49$). An interaction between statement type × group ($F_{3, 14} = 3.32$, $p = 0.03$, $\eta_p^2 = 0.17$) showed that the less-skilled group (2.6 ± 1.2) relied more heavily on kinematic information than the skilled group (1.9 ± 1.2), who reported more statements relating to sources of contextual information (skilled 0.5 ± 0.4, less-skilled 0.2 ± 0.2). There was a three-way interaction between statement type × group × context ($F_{3, 14} = 6.16$, $p < 0.01$, $\eta_p^2 = 0.49$; Figure 4). The skilled group reported more contextual statements (control 0.4 ± 0.2, context 2.7 ± 0.1) and less kinematic statements (control 2.4 ± 1.4, context 1.3 ± 1.0) in the presence of context. The less-skilled group still relied heavily on kinematic cues but did show a small increase in the reporting of sequence (control 0.1 ± 0.2, context 0.2 ± 0.4) and field position statements (control 0.1 ± 0.1, context 0.7 ± 0.6). The secondary task had no effect on the information sources reported (all $F \leq 3.05$, all $p > 0.05$).

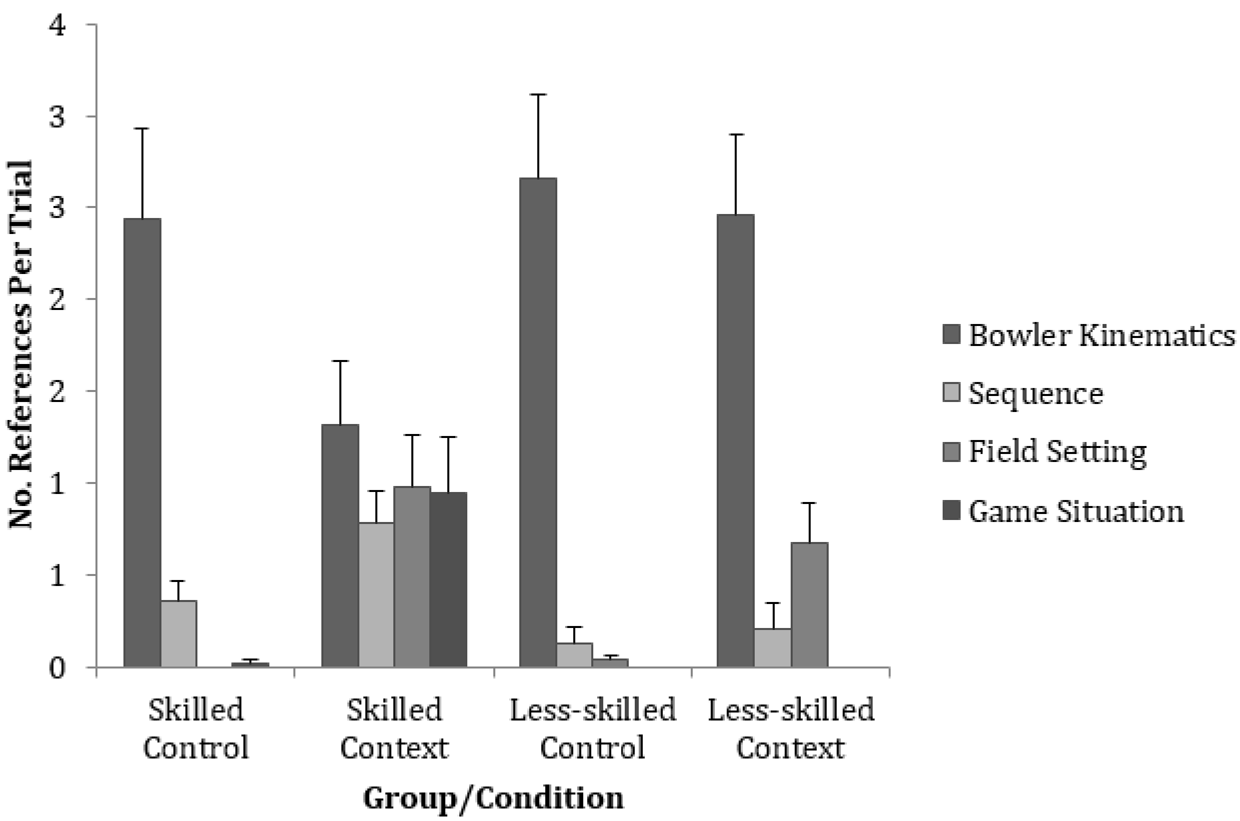

Figure 4. The verbal report statements relating to information sources used by each group in context and control conditions (with SE bars).

Discussion

We examined how context and the additions of a secondary task affected cognitive load and anticipation performance in skilled and less-skilled performers. In line with our hypothesis, the presence of context had a positive effect on anticipation accuracy for skilled participants, but contrary to our prediction less-skilled performers also improved their anticipation accuracy when contextual information was presented. These improvements occurred without affecting cognitive load measures for both groups, suggesting that context did not induce excessive cognitive load in the skilled or less-skilled performers. The improvement in anticipation performance when context was added replicates the findings of McRobert et al. (2011), who showed the addition of sequencing information improved anticipation accuracy in the same task. Moreover, our finding supports the suggestion made by Müller and Abernethy (2012) that skilled performers may generate situational probabilities based on context. Our novel finding that context was also advantageous for less-skilled performers without affecting cognitive load challenges the proposals of CLT that suggest such information would need to be consciously processed, thereby increasing extraneous load.

The verbal report data support the findings of McRobert et al. (2011) and Murphy et al. (2016). Skilled performers reported more statements relating to higher-order cognitive processes such as evaluation, planning, and prediction-type thoughts and the presence of contextual information added to this main effect. In contrast, less-skilled performers continued to rely mainly on stimulus-driven monitoring statements. The verbal report data revealed the extent to which the groups were able to use the different sources of contextual information available. Both groups referred to kinematic information from the bowler in the absence of context, but when context was provided skilled performers reported statements relating to sequencing and game information in addition to kinematic information. Both groups reported using information concerning opponent's positioning. As expected, skilled performers were able to integrate all the available sources of contextual information with kinematic sources to improve anticipation. These findings extend the work of Loffing and Hagemann (2014) by showing that the positions of opponents who do not directly play the ball themselves still affect anticipation and the underlying cognitive processes. Moreover, our data support the findings of Farrow and Reid (2012), who reported that the addition of game score information facilitates anticipation. Our results also support Paul and Glencross (1997), who showed that on-base position and count information in baseball had a significant impact on prediction of the pitch. In the future, researchers could systematically manipulate access to each source of information present in the specific task to quantify the degree to which each influences anticipation.

Although the less-skilled participants had no previous experience of competitive match-play, they reported using field settings and sequencing information, albeit sparsely, with no effect on cognitive load. These findings suggest that even a limited use of context was enough to have a significant impact on the anticipation performance of the less-skilled group. It is possible that the less-skilled group were able to quickly learn the relevance of the opposition field placings and this effect had a significant impact on anticipation accuracy. However, the less-skilled group did not report a single statement mentioning the use of the game score. This may be because a more detailed understanding of the game is required before this information source becomes relevant to the process, suggesting this may be an especially high-level process in this particular domain. Alternatively, it is possible that instead of attempting to take this information into account, the less-skilled batters elected to prioritize the information they could use that was relevant to the task and ignore other information sources, negating any extra load on working memory resources. It may be vital for less-skilled performers to quickly learn the relevance of contextual information sources in order to develop an understanding of congruency between context and kinematic information and the potential susceptibility to deception that could be present if relying solely on one source (e.g., Gray, 2002; Jackson, Warren, & Abernethy, 2006; Kunde, Skinde, & Weigelt, 2011).

The reliance upon kinematic information sources, in the absence of context, and the fact that even less-skilled performers could make some use of context, suggests that studies testing anticipation in the absence of context will have likely induced performers to be over-reliant on kinematic information. For example, while Muller et al. (2006) provided valuable insights and furthered knowledge and understanding around how advance postural cues inform anticipation, they did not consider the potential influence of context. The findings presented here, while only investigating the first stage of anticipation identified in Müller and Abernethy's (2012) model, suggest that the absence of available context prior to ball-release in previous investigations may have increased the performers' reliance on kinematic information, exaggerating the influence of this when compared to performance environments (i.e., match play) where additional information sources are present. In this study, we included contextual information sources and showed that skilled performers use this information in conjunction with kinematic information in a more balanced fashion to anticipate.

In contrast to our hypothesis and previous literature (e.g., Calvo & Ramos, 1989; Ellmers, et al., 2016), the introduction of a secondary task improved anticipation accuracy in both groups, while context had a larger positive effect on performance when coupled with a secondary task. This may have occurred because the primary anticipation task required the use of more automatic processes to combine high-order contextual information and lower-order sources of kinematic information, and because the secondary task induced more efficient processing by limiting explicit conscious control. Engström et al. (2017) suggested that adding cognitive load during a vehicle-driving task may only negatively affect processes under conscious control and could potentially have a positive effect on more automatic processes. The use of a secondary task could induce the prioritization of more relevant information sources in working memory and force the performer to ignore non-relevant sources in order to avoid overloading resources. This prioritization could result in the use of more simple heuristics such as 'Take The First', that have been shown to facilitate decision making performance in sports tasks (e.g., Johnson & Raab, 2003). Beyond the performance effect, CLT predicts that if working memory is taken up by the secondary task it is possible that learning will be hampered. Our findings from using a secondary-task introduces the possibility of extending the use of such tasks beyond measuring cognitive load to use in studies that test the impact of working memory resources on learning, as well as investigating the mechanisms that underpin how the secondary task improved anticipation accuracy.

Although we did not directly assess learning, by measuring cognitive load we are able to use the predictions of CLT to draw conclusions about how context in instructional design could potentially impact learning. By testing CLT and finding that context facilitated anticipation performance prior to ball release but did not increase task complexity to the extent that extraneous load and therefore cognitive load were affected, we offer support for the use of contextual information in representative learning environments to facilitate the development of anticipation in all levels of performer. Specifically, we have shown that even less-skilled performers have the ability to quickly learn the meaning of, and to use some specific sources of, contextual information to aid anticipation. However, some sources of context, such as game score, may require performers to have a more detailed understanding before they are used in training and so may reflect the highest level of cognitive processing utilized by skilled performers.

While we acknowledge the potential limitations of verbal reports, which may not account for sub-conscious processes that cannot be verbalised, we have addressed a gap in the understanding of anticipation identified by Müller and Abernethy (2012), by showing the relative importance of kinematic and contextual information and how they may interact prior to ball release. We used a novel combination of methods and a novel application of CLT to investigate the use of different information sources, including how these impact cognitive load in the anticipation process prior to ball release. However, we did not use multiple occlusion points to directly probe the use of information well before the bowler’s delivery stride, which would be important to explain the time at which context is used. In future, researchers should look to gain an understanding of how the importance of different information sources varies across time (e.g., from the start of the run-up to the moment of ball release in a cricket bowling task). Furthermore, the positive effect of the secondary task was unexpected and further investigation into the use of secondary tasks to induce the use of more automated processes is necessary (cf. Farrow, Reid, Buzzard, & Kovalchik, 2017).

In summary, we analyzed cognitive processes through verbal reports and coordinated survey instruments to examine how situation-specific context affects cognitive load and anticipation performance in skilled and less-skilled performers. We have shown that the presence of context facilitates anticipation accuracy in both groups, and that this occurred without any effect on cognitive load. A balanced use of different information sources such as sequencing, opponent field positioning and game score, and less reliance on the use of visual kinematic information sources underpinned skilled anticipation. These findings have implications for the use of Cognitive Load Theory in complex perceptual-motor tasks, as well as in the implementation of training designs that include contextual sources of information to improve the training of anticipation.

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