The Effect of Domain-Specific Exercise on High- and Low-Level Cognitive Processing During Anticipation

Colm P. Murphy[1]*

Joshua D. Hinde[2]

André Roca[2]

A. Mark Williams[3]

Jamie S. North[2]

[1]Cardiff School of Sport and Health Sciences, Cardiff Metropolitan University, Cardiff, United Kingdom

[2]Research Centre for Applied Performance Sciences, Faculty of Sport, Technology and Health Sciences, St Mary's University, Twickenham, London, UK

[3]Institute of Human and Machine Cognition, Pensacola, Florida, USA

*To whom correspondence should be addressed:

Cardiff School of Sport and Health Sciences

Cardiff Metropolitan University

Cyncoed Campus

Cyncoed Road

Cardiff CF23 6XD

UK

Email: cmurphy2@cardiffmet.ac.uk

ORCID: 0000-0002-8738-2181

Word count: 6,371

Abstract

Skilled anticipation is underpinned by the ability to synthesise high- (e.g., context) and low-level (e.g., biological motion) processes. While researchers have highlighted the effect of physiological load on the pick-up of biological motion from an opponent's kinematics, how such stress affects the use of contextual information has remained unexplored. In this paper, we conducted an experiment to examine how a fatigue-inducing, cricket-specific exercise protocol affects the use of contextual and kinematic information during anticipation. Altogether, 13 skilled batters completed a validated simulated cricket batting task designed to induce physiological responses representative of competition. Before, after, and during the exercise protocol, participants anticipated the end location of bowling deliveries that presented either opponent kinematics, contextual information (field positioning and game situation), or both. Anticipation responses were more accurate during the exercise protocol than at rest. Also, responses were more accurate when contextual information was available compared with when only kinematic cues were presented. Moreover, from the beginning to the end of the protocol, anticipation responses decreased in accuracy in those conditions in which contextual information was presented and increased in accuracy when only kinematic cues were available. We interpret the findings relative to Attentional Control Theory (Eysenck et al., 2007). Findings highlight the complex nature of expert sports performance and indicate that the effect of domain-specific exercise on anticipation is dependent on the physiological load experienced and the type of information available.

Keywords: Perceptual-cognitive skill; fatigue; expertise; cricket.

The Effect of Domain-Specific Exercise on High- and Low-Level Cognitive Processing during Anticipation

The extreme time constraints associated with interceptive tasks like cricket batting are such that, to respond effectively, athletes must judge the outcome of the delivery before the ball has left the bowler's hand (Müller & Abernethy, 2012; Regan, 1997; Runswick et al., 2020). To perform the task successfully, skilled batters use a combination of contextual information and kinematic cues (Runswick et al., 2020). Contextual information, derived from sources such as the placement of opponent fielders or game score, is associated with high-level cognitive processing as it is driven by prior experiences and the likelihood of different potential event outcomes (Murphy et al., 2016; Runswick et al., 2018a). Kinematic cues, such as the opponent's shoulder rotation or wrist flexion, likely engage lower-level cognitive processes with the performer picking up and utilising environmental cues, specifically biological motion, to inform their responses (Cocks et al., 2015; Ward et al., 2002). To make the challenge more complex, the need to engage with these processes varies over the course of an entire competitive encounter, during which batters are likely to experience increasing levels of physical and mental fatigue. While there have been efforts to examine how anticipation is affected by increased physiological demand (e.g., Alder et al., 2019; 2021; Casanova et al., 2022), to date researchers have focused on the pick-up of low-level environmental cues at the expense of higher-level cognitive processes (Murphy et al., 2019a). Given that expert performance is underpinned by the ability to synthesise high- and low-level processes (Murphy et al., 2016; Roca et al., 2013; Runswick et al., 2018a), we examined the effect of varying physiological demand as simulated using a cricket batting task on the use of contextual and kinematic information during anticipation.

Anticipation is underpinned by the ability to utilise contextual and kinematic sources of information (Farrow & Reid, 2012; Loffing & Hagemann, 2014; Runswick et al., 2018b). While expert performers can use the above sources of information in isolation of one another (Murphy et al., 2018; Runswick et al., 2018b), the ability to effectively process and integrate contextual and kinematic information sources appears crucial (Gray & Cañal-Bruland, 2018; Helm et al., 2020; Murphy et al., 2019b). When congruent with emerging kinematic cues, contextual information enhances anticipation, but when incongruent, context can impede anticipation (Mann et al., 2014). However, while some researchers have demonstrated that incongruence between context and kinematics negatively affects skilled anticipation (e.g., Jackson et al., 2020; Loffing et al., 2015; Runswick et al., 2018b), others have shown that any negative effect related to the incongruence between different information sources is minimal due to skilled athletes' ability to integrate and effectively prioritise information sources based on their reliability (Gredin et al., 2018; Müller et al., 2022).

The level of processing associated with the use of contextual and kinematic information sources has been shown to differ. Runswick et al. (2018a) collected retrospective verbal reports of thoughts from skilled cricket batters after viewing footage of cricket bowling deliveries that were presented either with or without contextual information related to the game situation and field positioning of the opposition players. When provided with the preceding context, the batters reported thoughts that indicated engagement with more higher-level cognitive processing of information such as evaluation and deep planning when compared with when only kinematic cues were presented (see also McRobert et al., 2011). This fundamental understanding of the levels of processing associated with the use of different information sources may explain how anticipation is influenced by stressors such as anxiety and fatigue.

As well as needing to adapt to the time constraints associated with high-speed striking tasks, expert cricket batters have to deal with the physical demands of competition. A successful “innings” can involve the batter performing in excess of 3.5 hours, covering a distance of approximately nine kilometres, without frequent rest periods (Petersen et al., 2010). During this time, batters must perform multiple moderate- and high-intensity sprints between the wickets to score runs, placing significant demand on the neuromuscular system. Such physiological load is likely to negatively affect anticipation, particularly in the latter phases of competition when the load is highest (e.g., Alder et al., 2019; Casanova et al., 2013; Klatt & Smeeton, 2021).

Alder et al. (2019) observed that, while completing a badminton-specific intermittent exercise protocol, expert badminton players’ anticipation of overhead smash shots was unaffected until the final of six blocks of the protocol, at which point there was a significant deterioration in response accuracy. Mental effort increased over the course of the protocol alongside an increase in the number of visual fixations made per second, as evidenced through self-report and gaze data, respectively. Processing Efficiency Theory (PET; Eysenck & Calvo, 1992), which was proposed to explain the effect of anxiety on performance, suggests that the increased load resulting from the exercise protocol could be compensated for by devoting more mental effort to the task, but only up to a certain point (i.e., maintained performance effectiveness but reduced processing efficiency). In the final block of the protocol, however, the load experienced exceeded the attentional resources required to maintain goal-directed behaviour (in this instance, effectively attending to task-relevant kinematic cues to anticipate the action outcome, cf. Casanova et al., 2013). While these findings provide an insight into how domain-specific exercise affects attention, contextual information was omitted from the design. Because effective anticipation is dependent on a combination of low- and high-level cognitive processes, from a theoretical perspective, there is a need to investigate how domain-specific exercise impacts the use of kinematic and contextual information sources.

Given the need to perform under increased physiological load across a range of sports and other domains, the exercise-cognition interaction has received much research attention (e.g., Cantelon & Giles, 2021; McMorris & Hale, 2015; Sudo et al., 2022). While contrasting findings do exist (e.g., Moreau & Chou, 2019), researchers have proposed an inverted-U relationship between exercise intensity and cognitive performance (Chang et al., 2012; McMorris, 2021), with moderate- and high-intensity exercise enhancing and impairing performance, respectively. Exercise yields metabolic, circulatory, and neurohormonal changes (Ide & Secher, 2000; Ogoh et al., 2014; Seifert & Secher, 2011), which in turn lead to increased brain activation in regions including, but not limited to, working memory, perception, and attention (Purves et al., 2001). While at moderate intensity, increases in brain activity appear to enhance cognitive performance, a drop in performance has been observed under high intensity, attributed to the brain’s finite resources (Dietrich & Audiffren, 2011; McMorris, 2021). In the psychology literature, Attentional Control Theory (ACT; Eysenck et al., 2007) has been proposed to build on Eysenck and Calvo’s (1992) PET by explaining how anxiety affects performance. Similar to how inverted-U theories were proposed to explain exercise effects on cognitive performance, ACT was proposed to explain how skilled performers’ attentional resources and subsequent performances are influenced under increased load or stress. Most recently, researchers have sought to test the predictions of

ACT in relation to the effects of physiological load on performance (e.g., see Alder et al., 2021).

ACT suggests that, in addition to processing efficiency being affected to a greater extent than performance effectiveness (in line with PET), under anxiety, attentional resources are directed towards threat-related stimuli. As a result, a shift from goal-directed to stimulus-driven attention occurs, implying that the ability to engage in higher- and lower-level cognitive processing is impaired and enhanced, respectively (Corbetta & Schulman, 2002; Eysenck et al., 2007). Cocks et al. (2015) provided support for this proposed shift in attentional systems when tennis players were required to anticipate under anxiety (see also Vater et al., 2015). Skilled tennis players were presented with footage from professional tennis matches that had been manipulated to display kinematic information only (video footage showing only the opponent striking the ball), contextual information only (the players were replaced by animated sticks to present only player positioning and shot sequencing), and both information sources (videos of the actual rallies played). While anxiety led to a significant drop in response accuracy when presented only with contextual information, performance was maintained if kinematic cues were available. Because contextual and kinematic information are associated with higher- and lower-level cognitive processing respectively, the researchers suggested that anxiety caused disengagement of goal-directed in favour of stimulus-driven attentional control. However, research is needed to determine whether such a shift in attentional systems underpins anticipation under increased physiological load.

It is important that scientists examine the effect of physiological load on anticipation using task demands that are representative of the competitive environment (Ericsson et al. 1993, Pinder et al., 2011). However, with few exceptions (e.g., Alder et al., 2019), researchers have employed non-domain-specific exercise protocols in which the way that physiological load is induced differs from what is experienced in competition (Schapschröer et al., 2016). Moreover, although skilled anticipation in striking sports is dependent on the exploitation of multiple information sources (Connor et al., 2020; Runswick et al., 2018b), our understanding of the effects of physiological load on anticipation is limited to the pick-up and utilisation of low-level kinematic cues. Therefore, in this paper, we examine the effect of a simulated cricket batting innings on the use of contextual and kinematic information during skilled anticipation. We employed an adapted version of the cricket-specific batting exercise (BATEX) simulation (Houghton et al., 2011) to induce physiological load over time. Participants took part in a video-based anticipation task in which kinematic information, contextual information, or both, were presented. The task was to predict the location at which the deliveries would pass the wicket based on the information available. The experiment consisted of eight blocks of trials in total, one before and one after the adapted BATEX protocol, acting as baseline data, with the remaining six integrated over the course of the protocol. Physiological measures such as heart rate (HR) and ratings of perceived exertion (RPE; Borg, 1998) were taken to ensure the adapted BATEX protocol increased physiological load, while the degree of mental effort required when completing the anticipation task was recorded to provide an indication of processing efficiency.

First, based on previous research highlighting the detrimental effects of physiological load on anticipation (e.g., Alder et al., 2021; Casanova et al., 2013), we hypothesised that anticipation responses would be less accurate at increasing workloads relative to rest. Second, we expected that anticipation responses would be most accurate when both kinematic and contextual information were available in comparison to when these sources were presented in isolation (Gredin et al., 2018; Murphy et al., 2016; Runswick et al., 2018a). We made further hypotheses as to observed effects during the adapted BATEX protocol. Based on previous research investigating the effect of a sport-specific exercise protocol on anticipation (Alder et al., 2019), we expected differences from the beginning to the end of the protocol. Alder et al. (2019) observed a drop in performance in the final of six blocks of a badminton-specific fatiguing protocol. However, given the information sources presented in the current experiment, and our interest in testing the predictions of ACT, we based our hypotheses on the findings of Cocks et al. (2015). We therefore expected anticipation accuracy to remain stable from the first to the final block of the adapted BATEX protocol when kinematic cues were presented, but for anticipation to become less accurate when participants were presented only with contextual information. We further expected mental effort to increase over the course of the protocol, indicating a reduction in processing efficiency (cf., Alder et al., 2019).

Materials and Methods

Participants

Based on the medium effect sizes reported by Alder et al. (2019), we conducted an a-priori power calculation using PANGEA v0.2 (Westfall, 2014). Of primary interest to us was the comparison of response accuracy across context conditions, from the beginning to the end of the adapted BATEX protocol, as previously researchers had not investigated how high- and low-level cognitive processing is affected by increased physiological load (Alder et al., 2019; Casanova et al., 2013). The analysis revealed that, for our 2 (Block [1, 6]) × 3 (Viewing Condition [Kinematics, Context, Combined]) interaction, thirteen participants would be sufficient to detect a medium effect size (0.5) with a power of 0.8. Thirteen skilled male cricket players (M_{age} = 23.38, *SD* = 6.44) took part. Participants had 15.23 years (*SD* = 7.52) experience playing cricket and had all played, or were currently playing, at county level or equivalent. Ethical approval was provided by the lead researcher's institution and all participants provided informed consent.

Test Stimuli

We used the test stimuli employed by McRobert et al. (2009) and adapted by Runswick et al. (2018a). Ten county level cricket bowlers (six fast and four spin bowlers) were filmed bowling towards a camera positioned on the batting crease in such a way that the typical viewing perspective of a batter was captured. The camera was set up at a height of 1.7 m and positioned in line with the middle stump. Six deliveries per bowler were recorded, representing a full over each, yielding 60 unique deliveries. A single block of 36 deliveries from Runswick et al. (2018a) was used with ten deliveries repeated, to create a block of 46 deliveries to best fit within the BATEX protocol (explained in full later). Trials were occluded immediately prior to hand-ball release. Contextual information that was congruent with the outcome of the bowl was associated with each delivery. A panel of three independent and qualified cricket coaches viewed each delivery until the ball passed the wickets and agreed upon a game situation and field that tactically aligned with the delivery. The coaching panel also certified that the contextual information was not deceptive, ensuring congruence between the contextual and kinematic information sources. Specifically, the game situation was made up of information related to the game score, the number of overs bowled, the number of runs scored, and the number of wickets taken at that point in the match (a one-day international, 50 over match). The field information was in the form of a schematic representation highlighting the positioning of each of the fielders relative to the wickets (see Runswick et al., 2019). Trials were created to present three viewing conditions:

context (game situation and field positioning only); kinematics (only the actual bowl being delivered); or combined (contextual followed by kinematic information).

Procedure

Testing occurred in an indoor sports centre. Participants were informed that their task was to imagine they were the batter and to judge where the bowler's delivery would pass the wicket. Prior to the experimental protocol beginning, participants viewed 6 familiarisation trials which provided two examples from each viewing condition. The bowlers presented during the familiarisation trials were those bowling in the experimental trials, however, the specific deliveries presented in the familiarisation trials were not used in the experimental test stimuli. Experimental trials comprised of 137 trials with 10 of the trials being viewed twice per viewing condition. Experimental trials were split into 8 blocks, namely, one baseline-pre block of 18 trials, one baseline-post block of 18 trials, and six blocks making up 101 trials interspersed within the adapted BATEX protocol. We randomised trial order and counterbalanced across participants. We presented test stimuli on a 160 cm x 120 cm screen using a horizontal keystone projector (Epson-X31, Japan), with participants standing approximately 5 m from the screen. When required to respond (once the footage occluded), participants marked on a piece of A4 paper where they anticipated the ball would pass the stumps on a diagram scaled down eight times from life size. We measured radial error by recording the distance between participants' judged location and the correct ball location. We then scaled back error to life size, highlighting how far the bat would have been from the ball. No feedback was provided to participants.

To induce physiological load that was representative of cricket competition, participants took part in an adapted version of the prolonged batting exercise (BATEX) simulation (Houghton et al., 2011). The validated BATEX protocol is designed to simulate scoring a One-Day International century (i.e., 100 runs). Participants are required to complete a series of runs between the wickets over the course of two hours, 20 minutes. The protocol is broken down into six consecutive, 21-minute blocks of five overs (30 deliveries total), with participants required to run at different intensities to represent the tempos associated with a competitive batting innings. Participants started in a position behind the crease line, holding their bat. All running between the wickets occurred over the length of a standard cricket pitch (17.68m, popping-crease to popping-crease). Participants were instructed (via an audio recording of the BATEX protocol) to run either singles (1 x 17.68m), 2s (2 x 17.68m), 3s (3 x 17.68m), or 4s (1.5 x 17.68m to represent the batter completing 1.5 runs before the ball crosses the boundary). Stages 1, 3, and 5 were completed at participants' "self-selected cruise pace", whereas stages 2, 4, and 6 were all completed at maximal speed. Participants had 35 seconds between deliveries and 80 seconds between overs, simulating the timings of a match and allowing participants sufficient time to rehydrate if required (Houghton et al., 2011). The original BATEX protocol required participants to physically bat a ball projected from a bowling machine. However, for the purpose of this experiment, the protocol was adapted to exclude the hitting component to minimise mental fatigue that may develop through cognitive processing associated with tracking ball flight (Romeas et al., 2019; Zhang et al., 2021). Over the course of the adapted BATEX protocol, participants completed a total of 79 runs, which were interspersed with 101 dot balls (i.e., those deliveries where no runs are scored). On dot balls, participants would move away from the crease and respond to an experimental trial before returning to their starting position (see Figure 1).

<<Insert Figure 1 around here>>

Participants wore full protective batting gear to mimic the demands of the competitive environment. However, gloves were not worn to allow participants to precisely complete a written response. To determine whether the BATEX protocol impacted on physiological load, participants wore a heart rate (HR) monitor (Polar M400, Kempele, Finland). HR was measured at baseline prior to participants warming up and watching the Baseline-Pre trials. Participants were familiarised with, and reported, their Rating of Perceived Exertion (Borg, 1998) at this point. RPE is a validated measure of how hard participants feel their body is working (ranging from 6 to 20: no exertion at all to maximal exertion). Both measures were taken following each block of the BATEX protocol and after the protocol had finished, immediately prior to watching the Baseline-Post trials. Timing gates (Brower timing systems, USA) were used to ensure participants' physical efforts did not deteriorate during the experiment, and that similar maximal sprint times were maintained throughout the protocol.

Finally, to determine how the level of mental effort required to complete the anticipation task was affected by physiological load, participants reported their mental effort on a visual analogue scale (measured from 0 to 100, with 0 representing little to no mental effort to complete the task, 50 representing moderate mental effort to complete the task, and 100 being maximal mental effort to complete the task). Participants marked the level of mental effort required to complete the anticipation task on the scale following each block of experimental test stimuli.

Data Analysis

First, to assess whether the adapted BATEX protocol was effective in increasing physiological load, we analysed changes in RPE and HR across the eight blocks of the protocol using a one-way Repeated Measures ANOVA. Next, to determine the effect of physiological load on anticipation accuracy across the three viewing conditions, we conducted an 8 (Block [Baseline-Pre, 1, 2, 3, 4, 5, 6, Baseline-Post]) × 3 (Viewing Condition [Kinematics, Context, Combined]) ANOVA. Because we hypothesised that a shift from the use of higher-level contextual to lower-level kinematic information would occur from the beginning to the end of the adapted BATEX protocol, we conducted a planned 2 (Block [1, 6]) × 3 (Viewing Condition [Kinematics, Context, Combined]) Repeated Measures ANOVA. Finally, to assess changes in mental effort involved in the anticipation task over the course of the experiment, we conducted a further one-way Repeated Measures ANOVA. In the case of violations of Mauchly's test of sphericity, we employed the Greenhouse-Geisser correction. Alpha (*p*) was set at .05 and Bonferroni adjustments were made to account for family-wise error in the case of multiple pairwise comparisons. Effect sizes were reported using partial eta squared (η_p^2) and Cohen's *d* values.

Results

Physiological Responses

The mean (*SD*) RPE and HR data are presented in Table 1. ANOVA revealed a main effect of Block on RPE, F (3.73, 44.75) = 110.64, $p < .05$, $\eta_p^2 = 0.90$. RPE was lowest during the baseline-pre (*M* = 7.00, *SD* = 1.55) and baseline-post (*M* = 9.50, *SD* = 1.22) phases and highest following the final block of the protocol (*M* = 17.33, *SD* = 1.86). Moreover, RPE increased over the course of the adapted BATEX protocol but was lower in the self-selected cruise pace blocks (Blocks 1, 3, and 5) which preceded the maximal speed blocks (Blocks 2, 4, and 6). A main effect of Block on HR was observed, F (7, 77) = 113.53, $p < .05$, $\eta_p^2 = 0.91$. Similarly, HR was lowest during the baseline-pre (*M* = 81.33, *SD* = 13.81) and baseline-post (*M* = 113.50, *SD* = 11.57) blocks with an increase in HR observed over the course of the protocol, peaking during the final block (*M* = 172.33, *SD* = 11.40). HR was also lower following the self-selected cruise pace blocks than the maximal speed blocks of the protocol.

<<Insert Table 1 around here>>

Anticipation Accuracy

The anticipation accuracy data (*M*, *SE* radial error) are presented in Figure 2. The 8 (Block) × 3 (Viewing Condition) repeated measures ANOVA revealed a main effect of Block, F (3.78, 45.40) = 2.89, $p < .05$, $\eta_p^2 = 0.19$. Overall, radial error was higher at rest (during the baseline periods, *M* = 42.28, *SD* = 8.60 cm) than during the BATEX protocol (*M* = 39.11, *SD* = 9.56 cm). Bonferroni-corrected post-hoc comparisons revealed that, specifically, participants were less accurate during the baseline-post block (*M* = 43.97, *SD* = 1.94 cm) compared with Block 4 (*M* = 38.70, *SD* = 2.15 cm, *d* = 0.48) and 5 (*M* = 38.95, *SD* = 1.77 cm, *d* = 0.58, both $p < .05$). A main effect of Viewing Condition was observed, F (1.36, 16.36) = 14.99, $p < .05$, $\eta_p^2 = 0.56$. Participants were more accurate in the context (*M* = 37.85, *SD* = 1.44 cm, *d* = 0.60) and combined (*M* = 38.70, *SD* = 1.68 cm, *d* = 0.50) conditions than in the kinematics only (*M* = 43.30, *SD* = 1.15 cm) condition, with no differences observed between the two conditions containing contextual information. The Block × Viewing Condition interaction was not significant.

<<Insert Figure 2 around here>>

To test our a priori prediction that a shift from the use of higher-level contextual information to lower-level kinematic cues would occur when participants were experiencing high levels of physiological load, we ran a further 2 (Block [1, 6]) × 3 (Viewing Condition [Context, Kinematics, Combined]) repeated measures ANOVA. A main effect of Viewing Condition was observed, F (2, 24) = 6.04, $p < .05$, $\eta_p^2 = 0.34$, with the context (*M* = 36.69, *SD* = 6.84 cm, *d* = .89) and combined (*M* = 37.39, *SD* = 7.90 cm) conditions again yielding higher accuracy scores than the kinematics condition

(*M* = 42.49, *SD* = 6.31 cm, *d* = 0.71). However, this effect was superseded by a Block × Viewing Condition interaction, *F* (2, 24) = 3.44, $p < .05$, $\eta_p^2 = 0.22$. When viewing trials presenting only kinematic information, anticipation accuracy increased from Block 1 (*M* = 44.33, *SD* = 4.11 cm) to Block 6 (*M* = 40.65, *SD* = 7.66 cm, *d* = 0.60). In contrast, in the context and combined conditions, anticipation accuracy decreased from Block 1 (Context: *M* = 34.54, *SD* = 6.07 cm; Combined: *M* = 35.09, *SD* = 3.54 cm) to Block 6 (Context: *M* = 38.83, *SD* = 7.12 cm, *d* = 0.65; Combined: *M* = 39.69, *SD* = 10.30 cm, *d* = 0.60).

Mental Effort

The ratings of mental effort (*M*, *SD*) are presented in Table 1. There was a main effect of Block on mental effort, *F* (2.15, 23.58) = 6.05, $p < .05$, $\eta_p^2 = 0.36$. Mental effort was higher when viewing trials during the later blocks of the adapted BATEX protocol than at other points. Specifically, mental effort was higher in Block 4 than Block 1 ($p < .05$, *d* = 0.98). Mental effort was also higher in Block 5 than Baseline-Pre ($p < .05$, *d* = 0.82), Block 1 ($p < .05$, *d* = 1.31), Block 2 ($p < .05$, *d* = 1.08), and Block 3 ($p < .05$, *d* = 0.83). Finally, mental effort was higher in Block 6 than Block 2 ($p < .05$, *d* = 1.27) and Block 3 ($p < .05$, *d* = 1.06).

Discussion

We examined the effect of cricket-specific exercise on the ability of skilled cricket batters to utilise kinematic and contextual information to anticipate the end location of bowling deliveries. We hypothesised that response accuracy would be lower during the adapted BATEX protocol than at rest (Alder et al., 2021; Casanova et al., 2013), and that response accuracy would be highest when contextual and kinematic information were available (Murphy et al., 2016; Runswick et al., 2018a). We further hypothesised, based on ACT (Eysenck et al., 2007) and supporting research (Cocks et al., 2015), that from the beginning to the end of the adapted BATEX protocol, response accuracy would remain stable in the kinematic and combined conditions, but drop in the context condition. Finally, we expected an increase in mental effort to occur over the course of the protocol (Alder et al., 2019).

Contrary to our first hypothesis, response accuracy was higher during the adapted BATEX protocol than at rest. We had expected that the level of physiological load resulting from the protocol would have a negative effect on performance. However, the effect of physiological load on perceptual-cognitive skill appears to be dependent on the degree of load experienced. While high physiological load appears to yield detrimental effects (e.g., Alder et al., 2021; Casanova et al., 2013; Casanova et al., 2022), moderate load has been shown to have a positive effect on anticipation (Alder et al., 2019). Exercise leads to increased arousal levels and, as per inverted-U theories (e.g., Chang et al., 2012; Easterbrook, 1959; McMorris, 2021), while moderate levels of arousal optimise performance, high levels detrimentally affect attention and cognition (Brisswalter et al., 2002; Hütterman & Memmert, 2012). Given that the adapted BATEX protocol is made up of three bouts each of self-selected cruise pace and maximal speed exercise, the moderate load participants experienced (M_{HR} = 137.00, SD = 25.82; M_{RPE} = 13.96, SD = 2.70) during the protocol yielded positive effects, overall. However, while the current experiment was designed to represent the physical demands of competitive cricket (Pinder et al., 2011), it lacked the sensitivity to compare across clearly defined levels of physiological load. In future, there would be value in systematically investigating the effect of different levels of physiological load on the processes underpinning anticipation (Alder et al., 2021; McMorris & Hale, 2015).

In line with our second hypothesis, the combined condition yielded higher response accuracy than the kinematic condition. This finding was expected, as previously researchers have demonstrated that the availability of contextual information enhances anticipation when the contextual and kinematic sources are congruent with one another, as was the case in this experiment (Gredin et al., 2018; Müller et al., 2022; Runswick et al., 2019). This finding further highlights the multidimensional nature of expert anticipation (Cañal-Bruland & Mann, 2015; Runswick et al., 2020), and the importance of employing test stimuli that more fully represent the information sources available in competition than has been employed to date (Ericsson et al., 1993; Pinder et al., 2011). The skilled batters were able to integrate contextual and kinematic cues to anticipate more effectively than when relying purely on opponent kinematics (Gredin et al., 2018; Gredin et al., 2020; Runswick et al., 2020). However, it is possible that performance was enhanced not by the integration of contextual and kinematic cues, but because of greater reliance on what was deemed more reliable contextual information. Response accuracy in the context condition being higher than in the kinematics only condition but no different to the combined condition suggests this to be a strong possibility. This finding is important because, while previously researchers have shown that skilled anticipation during cricket batting can be equally as accurate when presented solely with contextual information as when kinematic cues are also available (Müller et al., 2022; Runswick et al., 2018b), it is the first paper, to our knowledge to show that contextual information may facilitate anticipation to a greater extent than kinematic cues when either source is presented in isolation. It is likely though, that reliance on, and the utility of different information sources, varies between sports (e.g., for contrasting findings in tennis, see Cocks et al., 2015), and situations within sports (McRobert et al., 2011; Roca et al., 2013).

When comparing the final to the first block of the adapted BATEX protocol, we observed a drop in response accuracy in both the context and combined conditions, and an increase in accuracy in the kinematics condition. This finding aligns with ACT (Eysenck et al., 2007), which proposes a shift from goal-directed to stimulus-driven attentional control under increased load. The elevated levels of physiological load experienced towards the end of the protocol appear to have led to a reduction in the ability of skilled batters to engage in high-level cognitive processing of contextual information, and an increased ability to engage in low-level processing of kinematic cues. While we speculate that our findings indicate a shift in attentional control, in future, researchers should incorporate the collection of gaze data to verify this suggestion (e.g., Alder et al., 2021; Vater et al., 2015; Wilson et al., 2009).

Our findings contrast somewhat with those of Cocks et al. (2015), who observed that anxiety detrimentally affected performance only when participants were constrained to anticipate based on context alone. No such effect was observed when participants were presented with kinematics alone or a combination of both context and kinematics. When viewing tennis rallies, players remained robust to anxiety when both information sources were presented, suggesting a shift towards the use of low-level kinematic cues was beneficial to maintaining performance. In the current experiment, under increased physiological load, anticipation accuracy was enhanced when constrained to utilise kinematic cues in isolation but impeded in both conditions when contextual information was available (i.e., in the context and combined conditions). It follows that the impact of stressors such as anxiety or physiological load may be task-dependent, with the relative reliability of information sources influencing how their use and subsequently, performance, is affected. In tennis rallies (Cocks et al., 2015), a greater weighting on kinematic over contextual information may have meant that a reduction in players' ability to engage in high-level cognitive processing did not impact performance when both information sources were available. In contrast, when batting, skilled cricket players may deem contextual information to be more reliable than kinematic cues, meaning a reduced ability to engage in higher-level cognitive processing yielded a drop in performance. This interpretation is supported by higher accuracy scores being observed when viewing kinematic information alone or contextual information alone in the Cocks et al. (2015) paper and the current experiment, respectively.

The degree of mental effort participants required to complete the anticipation task was higher in the later compared with the earlier stages of the protocol or prior to commencing the protocol. In support of ACT (Eysenck et al., 2007), to account for the increased attentional demands imposed by the adapted BATEX protocol, participants maintained performance levels through investment of greater mental effort (maintenance of goal-directed behaviour at the expense of processing efficiency). While this finding aligns with those of Alder et al. (2019), increased physiological load resulting from sport-specific exercise had differential effects on the use of low-level kinematic cues across both experiments. Alder et al. (2019) observed that the ability of skilled badminton players to pick up kinematic cues to anticipate the end location of overhead smash shots in badminton dropped under high physiological load, whereas our findings suggest a reduced ability to utilise contextual information but an enhanced ability to utilise kinematic cues. While further investigation of the cause of this difference is required, we tentatively suggest that it may arise due to the requirements of effective anticipation across the different sports. For example, while a more global strategy for picking up kinematic information has been deemed important for anticipating striking actions such as tennis serves or forehands (e.g., Huys et al., 2009; Jackson & Mogan, 2007), it is the pick-up of local information from the arm-hand region that seems critical for effective anticipation when batting in cricket (Müller et al., 2006; Müller et al., 2010). Therefore, the attentional narrowing that results from high physiological load (Easterbrook, 1959; Hütterman & Memmert, 2012) may impair anticipation in some tasks and enhance it in others.

Several implications emerge from this research. First, the adapted BATEX protocol, which appeared to elucidate, on average, moderate levels of physiological load, had a positive effect on the ability of skilled cricket batters to anticipate opponent intentions. Therefore, not only can physical warm-ups yield more effective physical performance (Fradkin et al., 2010; Silva et al., 2018) but the associated physiological stimulus may act to prime the athlete for perceptual-cognitive-motor performance. In sports like cricket, the moment at which batters will be required to bat is unpredictable. However, given that our findings highlight better anticipation when active than at rest, batters should aim to engage in cricket-specific exercise immediately prior to performing. Second, in the current experiment, the ability to utilise kinematic cues was enhanced under high physiological load, while performance dropped when contextual information was presented. These findings appear to suggest that directing attention towards kinematic information, as opposed to contextual information, could prove to be an effective strategy for sustaining performance under periods of fatigue. However, despite the drop in performance when contextual information was available, performance levels in the final block of the exercise protocol did not differ across viewing conditions. Given that, over the course of the experiment, anticipation accuracy was highest when contextual information was available, we propose that researchers should focus on devising training methods that practitioners can employ to enhance athletes' robustness to physiological load, such that a combination of low- and high-level cognitive processing can be effectively maintained after prolonged periods of domain-specific exercise. While researchers have demonstrated that training under physical load (Alder et al., 2019) can develop anticipation skills that are more robust to similar demands in future, the focus to date has been on the pick-up of low-level kinematic cues. However, should the opponent be effective in displaying deceptive intent, which reduces skilled athletes' ability to anticipate based on kinematic cues (Jackson et al., 2018; Jackson et al., 2020; Ramsey et al., 2022), effective utilisation of contextual information will be critical.

The experiment we conducted is not without limitations. The pen-and-paper response resulted in a decoupling of perception and action, potentially reducing the extent to which findings represent expert performance in the competitive environment (Mann et al., 2010; van der Kamp et al., 2008). However, much of our knowledge of skilled performance has emerged from studies using verbal (Crowther et al., 2023), written (Runswick et al., 2018b) or button press responses (Mann et al., 2014) and psychologists are increasingly acknowledging the cognition-action interaction that underpins skilled motor performance (Christensen et al., 2016; Wang et al., 2021). We therefore suggest that our approach is warranted to advance our understanding of anticipation, especially considering the current challenges associated with exploring this issue while maintaining perception-action couplings. The use of a validated batting simulation (Houghton et al., 2011) to increase physiological load means that we can be confident that the physical demands of the task were representative of the competitive environment. Moreover, researchers have highlighted the importance of representative test stimuli (Kalén et al., 2021), which we achieved through the presentation of life-size images and incorporation of information sources that would be available in the competitive environment. On this note, in future, researchers could increase the representative nature of the test stimuli. For example, for reasons of control, we randomised the presentation of the bowlers to participants. However, in the real word, bowlers will have the opportunity to pick up contextual information about bowler tendencies as they become familiar with them over a series of sequential bowls (McRobert et al., 2011).

Another limitation lies in the way mental effort was measured. Because mental effort was measured after each block rather than each trial (due to time constraints), the rating only provided an indication of how mental effort changed over the course of the experiment, irrespective of viewing condition. Being able to compare how mental effort changed over the course of the experiment in the different viewing conditions would have allowed us to assess the extent to which ACT can explain the effects of physiological load on anticipation more confidently. For example, we would expect mental effort to be higher when using contextual information alone to anticipate, due to the need to engage with more higher-level cognitive processes to form judgements (Cocks et al., 2015). An interesting avenue for future research would therefore be to investigate how processing efficiency, specifically, varies during incremental bouts of exercise when individuals are presented with information sources requiring low- and high-level cognitive processing.

To conclude, we have demonstrated that the effect of sport-specific exercise on skilled anticipation appears dependent on the degree of load and the type of information employed. In line with ACT, under high physiological load a shift from goal-directed to stimulus-driven attention was evident, impairing and enhancing performance when higher-level contextual information was, or was not, presented, respectively. In future, research is required to investigate the effect of physiological load on anticipation in tasks that differ in their requirements for effective anticipation (e.g., when the reliability of information sources differ). Our findings provide further evidence of the complex nature of expert sports performance.

Disclosure Statement

No potential conflict of interest was reported by the author(s).

Data Availability Statement

Data can be provided by the first author upon reasonable request.

References

Alder, D., Broadbent, D. P., & Poolton, J. (2021). The combination of physical and mental load exacerbates the negative effect of each on the capability of skilled soccer players to anticipate action. *Journal of Sports Sciences, 39*, 1030-1038.

Alder, D. B., Broadbent, D. P., Stead, J., & Poolton, J. (2019). The impact of physiological load on anticipation skills in badminton: From testing to training. *Journal of Sports Sciences*, *37*, 1816-1823.

Borg, G. (1998). *Borg's perceived exertion and pain scales*. Human Kinetics.

Brisswalter, J., Collardeau, M., & René, A. (2002). Effects of acute physical exercise characteristics on cognitive performance. *Sports Medicine*, *32*(9), 555-566.

Cañal-Bruland, R., & Mann, D. L. (2015). Time to broaden the scope of research on anticipatory behavior: A case for the role of probabilistic information. *Frontiers in Psychology, 6*, 1518.

Cantelon, J. A., & Giles, G. E. (2021). A review of cognitive changes during acute aerobic exercise. *Frontiers in Psychology, 12*, 653158.

Casanova, F., Garganta, J., Silva, G., Alves, A., Oliveira, J., & Williams, A. M. (2013). Effects of prolonged intermittent exercise on perceptual-cognitive processes. *Medicine and Science in Sports and Exercise*, *45*(8), 1610-1617.

Casanova, F., Esteves, P. T., Padilha, M. B., Ribeiro, J., Williams, A. M., & Garganta, J. (2022). The Effects of Physiological Demands on Visual Search Behaviours During 2 vs. 1+ GK Game Situations in Football: An in-situ Approach. *Frontiers in Psychology*, *13*, 885765.

Chang, Y. K., Labban, J. D., Gapin, J. I., & Etnier, J. L. (2012). The effects of acute exercise on cognitive performance: a meta-analysis. *Brain Research*, *1453*, 87-101.

Christensen, W., Sutton, J., & McIlwain, D. J. (2016). Cognition in skilled action: Meshed control and the varieties of skill experience. *Mind & Language*, *31*(1), 37-66.

Cocks, A. J., Jackson, R. C., Bishop, D. T., & Williams, A. M. (2015). Anxiety, anticipation and contextual information: A test of attentional control theory. *Cognition and Emotion*, *30*(6), 1037-1048.

Connor, J. D., Renshaw, I., & Farrow, D. (2020). Defining cricket batting expertise from the perspective of elite coaches. *Plos One*, *15*(6), e0234802.

Corbetta, M., & Shulman, G. L. (2002). Control of goal-directed and stimulus-driven attention in the brain. *Nature Reviews Neuroscience*, *3*(3), 201-215.

Crowther, R. H., Renshaw, I., Spratford, W. A., Sayers, M. G., & Gorman, A. D. (2023). Previous experiences can influence individual cricket spin bowlers' perceptions of affordances in the performance landscape. *Psychological Research*, 1-14.

Dietrich, A., & Audiffren, M. (2011). The reticular-activating hypofrontality (RAH) model of acute exercise. *Neuroscience & Biobehavioral Reviews*, *35*(6), 1305-1325.

Easterbrook, J. A. (1959). The effect of emotion on cue utilization and the organization of behavior. *Psychological Review*, *66*(3), 183.

Ericsson, K. A., Krampe, R. T., & Tesch-Römer, C. (1993). The role of deliberate practice in the acquisition of expert performance. *Psychological Review*, *100*(3), 363-406.

Eysenck, M. W., & Calvo, M. G. (1992). Anxiety and performance: The processing efficiency theory. *Cognition & Emotion*, *6*(6), 409-434.

Eysenck, M. W., Derakshan, N., Santos, R., & Calvo, M. G. (2007). Anxiety and cognitive performance: attentional control theory. *Emotion*, *7*(2), 336-353.

Farrow, D., & Reid, M. (2012). The contribution of situational probability information to anticipatory skill. *Journal of Science and Medicine in Sport*, *15*, 368-373.

Fradkin, A. J., Zazryn, T. R., & Smoliga, J. M. (2010). Effects of warming-up on physical performance: a systematic review with meta-analysis. *The Journal of Strength & Conditioning Research*, *24*(1), 140-148.

Gray, R., & Cañal-Bruland, R. (2018). Integrating visual trajectory and probabilistic information in baseball batting. *Psychology of Sport and Exercise*, *36*, 123-131.

Gredin, N. V., Bishop, D. T., Broadbent, D. P., Tucker, A., & Williams, A. M. (2018). Experts integrate explicit contextual priors and environmental information to improve anticipation efficiency. *Journal of Experimental Psychology: Applied*, *24*(4), 509-520.

Gredin, N. V., Bishop, D. T., Williams, A. M., & Broadbent, D. P. (2020). The use of contextual priors and kinematic information during anticipation in sport: toward a Bayesian integration framework. *International Review of Sport and Exercise Psychology*, 1-25.

Helm, F., Cañal-Bruland, R., Mann, D. L., Troje, N. F., & Munzert, J. (2020). Integrating situational probability and kinematic information when anticipating disguised movements. *Psychology of Sport and Exercise*, *46*, 101607.

Houghton, L., Dawson, B., Rubenson, J., & Tobin, M. (2011). Movement patterns and physical strain during a novel, simulated cricket batting innings (BATEX). *Journal of Sports Sciences*, *29*(8), 801-809.

Hüttermann, S., & Memmert, D. (2012). Moderate movement, more vision: Effects of physical exercise on inattentional blindness. *Perception*, *41*(8), 963-975.

Huys, R., Cañal-Bruland, R., Hagemann, N., Beek, P. J., Smeeton, N. J., & Williams, A. M. (2009). Global information pickup underpins anticipation of tennis shot direction. *Journal of Motor Behavior, 41*, 158-170.

Ide, K., & Secher, N. H. (2000). Cerebral blood flow and metabolism during exercise. *Progress in Neurobiology, 61*(4), 397-414.

Jackson, R. C., Barton, H., Ashford, K. J., & Abernethy, B. (2018). Stepovers and signal detection: Response sensitivity and bias in the differentiation of genuine and deceptive football actions. *Frontiers in Psychology*, *9*, 2043.

Jackson, R. C., Barton, H., & Bishop, D. T. (2020). Knowledge is power? Outcome probability information impairs detection of deceptive intent. *Psychology of Sport and Exercise*, *50*, 101744.

Jackson, R. C., & Mogan, P. (2007). Advance visual information, awareness, and anticipation skill. *Journal of Motor Behavior, 39*, 341-351.

Kalén, A., Bisagno, E., Musculus, L., Raab, M., Pérez-Ferreirós, A., Williams, A. M., ... & Ivarsson, A. (2021). The role of domain-specific and domain-general cognitive functions and skills in sports performance: A meta-analysis. *Psychological Bulletin*, *147*(12), 1290-1308.

Klatt, S., & Smeeton, N. J. (2021). Attentional and perceptual capabilities are affected by high physical load in a simulated soccer decision-making task. *Sport, Exercise, and Performance Psychology*, *10*(2), 205.

Loffing, F., & Hagemann, N. (2014). On-court position influences skilled tennis players' anticipation of shot outcome. *Journal of Sport & Exercise Psychology, 36*, 14-26.

Loffing, F., Stern, R., & Hagemann, N. (2015). Pattern-induced expectation bias in visual anticipation of action outcomes. *Acta Psychologica*, *161*, 45-53.

Mann, D. L., Abernethy, B., & Farrow, D. (2010). Action specificity increases anticipatory performance and the expert advantage in natural interceptive tasks. *Acta Psychological*, *135*(1), 17-23.

Mann, D. L., Schaefers, T., & Cañal-Bruland, R. (2014). Action preferences and the anticipation of action outcomes. *Acta Psychologica*, *152*, 1-9.

McMorris, T. (2021). The acute exercise-cognition interaction: From the catecholamines hypothesis to an interoception model. *International Journal of Psychophysiology*, *170*, 75-88.

McMorris, T., & Hale, B. J. (2015). Is there an acute exercise-induced physiological/biochemical threshold which triggers increased speed of cognitive functioning? A meta-analytic investigation. *Journal of Sport and Health Science*, *4*(1), 4-13.

McRobert, A. P., Ward, P., Eccles, D. W., & Williams, A. M. (2011). The effect of manipulating context-specific information on perceptual–cognitive processes during a simulated anticipation task. *British Journal of Psychology*, *102*(3), 519-534.

McRobert, A. P., Williams, A. M., Ward, P., & Eccles, D. W. (2009). Tracing the process of expertise in a simulated anticipation task. *Ergonomics, 52*(4), 474-483.

Moreau, D., & Chou, E. (2019). The acute effect of high-intensity exercise on executive function: a meta-analysis. *Perspectives on Psychological Science*, *14*(5), 734-764.

Müller, S., & Abernethy, B. (2012). Expert anticipatory skill in striking sports: A review and a model. *Research Quarterly for Exercise and Sport*, *83*, 175-187.

Müller, S., Abernethy, B., Eid, M. McBean, R., & Rose, M. (2010). Expertise and the spatio-temporal characteristics of anticipatory information pick-up from complex movement patterns. *Perception, 39*, 745-760.

Müller, S., Abernethy, B., & Farrow, D. (2006). How do world-class cricket batsmen anticipate a bowler's intention? *The Quarterly Journal of Experimental Psychology, 59*, 2162-2186.

Müller, S., Brenton, J., & O'Grady, M. (2022). Reliance upon contextual information can impede visual anticipation. *European Journal of Sport Science*, 1-27.

Murphy, C. P., Jackson, R. C., Cooke, K., Roca, A., Benguigui, N., & Williams, A. M. (2016). Contextual information and perceptual-cognitive expertise in a dynamic, temporally-constrained task. *Journal of Experimental Psychology: Applied*, *22*, 455-470.

Murphy, C. P., Jackson, R. C., & Williams, A. M. (2018). The role of contextual information during skilled anticipation. *Quarterly Journal of Experimental Psychology*, *71*(10), 2070-2087.

Murphy, C. P., Jackson, R. C., & Williams, A. M. (2019a). Contextual information and its role in expert anticipation. In *Anticipation and decision making in sport* (pp. 43-58). Routledge.

Murphy, C. P., Jackson, R. C., & Williams, A. M. (2019b). Informational constraints, option generation, and anticipation. *Psychology of Sport and Exercise*, *41*, 54-62.

Ogoh, S., Tsukamoto, H., Hirasawa, A., Hasegawa, H., Hirose, N., & Hashimoto, T. (2014). The effect of changes in cerebral blood flow on cognitive function during exercise. *Physiological Reports*, *2*(9), e12163.

Petersen, C. J., Pyne, D., Dawson, B., Portus, M., & Kellett, A. (2010). Movement patterns in cricket vary by both position and game format. *Journal of Sports Sciences*, *28*(1), 45-52.

Pinder, R. A., Davids, K., Renshaw, I., & Araújo, D. (2011). Representative learning design and functionality of research and practice in sport. *Journal of Sport and Exercise Psychology*, *33*(1), 146-155.

Purves, D., Augustine, G., Fitzpatrick, D. (2001). *Neuroscience*. 2nd ed. Sinaur Associates.

Ramsey, H., Dicks, M., Hope, L., & Reddy, V. (2022). Maximising grip on deception and disguise: Expert sports performance during competitive interactions. *Sports Medicine-Open*, *8*(1), 1-9.

Regan, D. (1997). Visual factors in hitting and catching. *Journal of Sports Sciences, 15*, 533-558.

Roca, A., Ford, P. R., McRobert, A. P., & Williams, A. M. (2013). Perceptual-cognitive skills and their interaction as a function of task constraints in soccer. *Journal of Sport & Exercise Psychology*, *35*, 144-155.

Romeas, Chaumillon, R., Labbé, D., & Faubert, J. (2019). Combining 3D-MOT with sport decision-making for perceptual-cognitive training in Virtual Reality. *Perceptual and Motor Skills*, *126*(5), 922–948.

Runswick, O. R., Roca, A., Mark Williams, A., Bezodis, N. E., McRobert, A. P., & North, J. S. (2018a). The impact of contextual information and a secondary task on anticipation performance: An interpretation using cognitive load theory. *Applied Cognitive Psychology*, *32*(2), 141-149.

Runswick, O. R., Roca, A., Williams, A. M., McRobert, A. P., & North, J. S. (2018b). The temporal integration of information during anticipation. *Psychology of Sport and Exercise*, *37*, 100-108.

Runswick, O. R., Roca, A., Williams, A. M., McRobert, A. P., & North, J. S. (2019). Why do bad balls get wickets? The role of congruent and incongruent information in anticipation. *Journal of Sports Sciences*, *37*(5), 537-543.

Runswick, O. R., Roca, A., Williams, A. M., & North, J. S. (2020). A model of information use during anticipation in striking sports (MIDASS). *Journal of Expertise*, *3*(4), 197-211.

Schapschröer, M., Lemez, S., Baker, J., & Schorer, J. (2016). Physical load affects perceptual-cognitive performance of skilled athletes: A systematic review. *Sports Medicine-Open*, *2*, 1-16.

Seifert, T., & Secher, N. H. (2011). Sympathetic influence on cerebral blood flow and metabolism during exercise in humans. *Progress in Neurobiology*, *95*(3), 406-426.

Silva, L. M., Neiva, H. P., Marques, M. C., Izquierdo, M., & Marinho, D. A. (2018). Effects of warm-up, post-warm-up, and re-warm-up strategies on explosive efforts in team sports: A systematic review. *Sports Medicine*, *48*(10), 2285-2299.

Sudo, M., Costello, J. T., McMorris, T., & Ando, S. (2022). The effects of acute high-intensity aerobic exercise on cognitive performance: A structured narrative review. *Frontiers in Behavioral Neuroscience*, 380.

van der Kamp, J., Rivas, F., van Doorn, H., & Savelsbergh, G. (2008). Ventral and dorsal system contributions to visual anticipation in fast ball sports. *International Journal of Sport Psychology*, *39*, 100-130.

Vater, C., Roca, A., & Williams, A. M. (2015). Effects of anxiety on anticipation and visual search in dynamic, time-constrained situations. *Sport, Exercise, and Performance Psychology*, *5*(3), 179-192.

Wang, K. P., Frank, C., Tsai, Y. Y., Lin, K. H., Chen, T. T., Cheng, M. Y., ... & Schack, T. (2021). Superior performance in skilled golfers characterized by dynamic neuromotor processes related to attentional focus. *Frontiers in Psychology*, *12*, 633228.

Westfall, J., Kenny, D. A., & Judd, C. M. (2014). Statistical power and optimal design in experiments in which samples of participants respond to samples of stimuli. *Journal of Experimental Psychology: General*. *143*, 2020–2045.

Ward, P., Williams, A. M., & Bennett, S. J. (2002). Visual search and biological motion perception in tennis. *Research Quarterly for Exercise and Sport, 73*, 107-112.

Wilson, M. R., Wood, G., & Vine, S. J. (2009). Anxiety, attentional control, and performance impairment in penalty kicks. *Journal of Sport and Exercise Psychology*, *31*(6), 761-775.

Zhang, Y., Lu, Y., Wang, D., Zhou, C., & Xu, C. (2021). Relationship between individual alpha peak frequency and attentional performance in a multiple object tracking task among ice-hockey players. *Plos One*, *16*(5), e0251443.

Tables

Table 1. Mean (*SD*) RPE, HR, and mental effort across blocks of the adapted BATEX protocol.

		Block							
		Baseline-pre	1	2	3	4	5	6	Baseline-post
RPE	*M*	7.00	10.50	13.67	12.50	16.00	13.67	17.33	9.50
	SD	1.55	0.55	0.82	1.52	1.10	1.75	1.86	1.22
HR	*M*	81.33	118.00	144.33	122.00	157.17	140.33	172.33	113.50
	SD	13.81	12.49	24.80	22.70	18.30	12.86	11.40	11.57
Mental effort	*M*	41.65	34.62	40.54	43.17	52.46	58.00	65.54	57.38
	SD	22.68	18.89	15.35	18.73	17.40	16.87	23.30	31.73

Figures

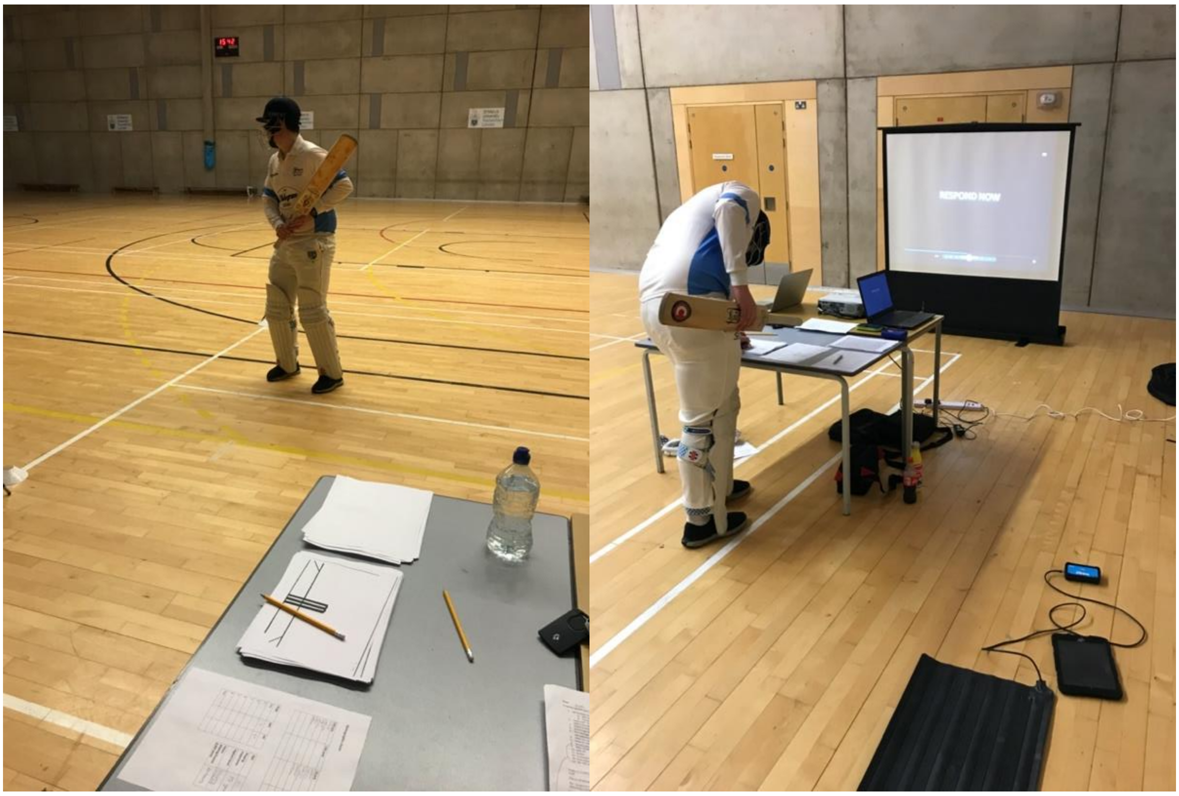

Figure 1. Testing set-up

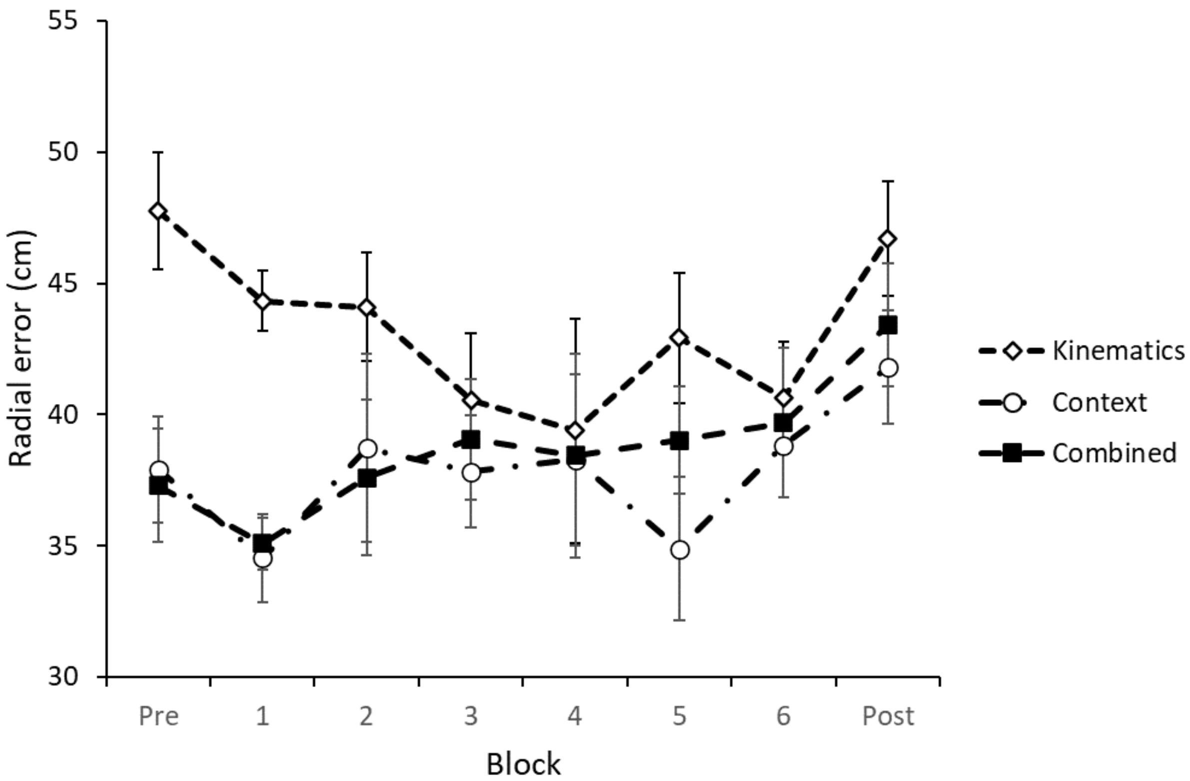

Figure 2. Mean (*SE*) radial error (cm) over blocks and across viewing conditions.

Figure Captions

Figure 1. Testing set-up

Figure 2. Mean (*SE*) radial error (cm) over blocks and across viewing conditions.