The combination of physical and mental load exacerbates the negative effect of each on the capability of skilled soccer players to anticipate action

Abstract

This study examined the impact of combining physical and mental load on the anticipatory judgements of skilled soccer players. Sixteen players completed an 11vs11 video anticipation test in four counterbalanced conditions, each separated by seven days. The baseline condition consisted of only the anticipation test. A physical load condition required participants to complete a simulated soccer protocol on a treadmill followed by the anticipation test. A mental load condition required participants to complete a 30-minute Stroop test followed by the anticipation test. Finally, in the combined load condition, participants completed the physical load protocol alongside the mentally loading Stroop task followed by the anticipation test. Response accuracy, visual search behaviour and measures of effort were assessed throughout. Response accuracy decreased in the separate physical load and mental load conditions when compared to baseline and worsened further in the combined load condition. The reduction in response accuracy across experimental conditions coincided with an increase in the number of fixations when compared to the baseline condition. It is suggested that the separate sources of load impaired the players ability to allocate sufficient resources to task-relevant information leading to a reduction in anticipatory accuracy, and this was exacerbated in the combined load condition.

Key words; Visual search, Anticipation, Expertise, Mental Fatigue, Physical Fatigue

Introduction

Severe temporal demands force athletes to anticipate, rather than react, to the actions of opponents in order to be successful (Williams & Jackson, 2019). A substantial body of work has demonstrated that the capability to identify, fixate upon and extract cues from information rich areas is an attribute common to skilled athletes (for a review, see Mann et al., 2007). Roca and colleagues (2013) report how the superior anticipatory performance of elite soccer player was accompanied with adaptive context dependent visual search behaviours. Similar findings have been demonstrated across racket (Alder et al., 2019; Ward, Williams & Bennett, 2002), striking and fielding (McRobert et al., 2009), and combat sports (Ripoll et al., 1995). If, as described, skilled anticipatory judgements are supported by specific visual search behaviours that are specific to both sport and task (Mann et al., 2007), then additional loads within the environment that might compromise the effectiveness and efficiency of visual search should be appreciated.

In many sports, an additional physical load accumulates as a function of the competition (Anderson et al., 2016). For example, in a 90-minute game, elite level soccer players are required to cover large distances (Dellal et al., 2010) at high speeds (Andrzejewski et al., 2013) and complete numerous accelerations and decelerations (Dellal et al., 2012). Not only does high physical load negatively impact the gross physical output (Arruda et al., 2015) and the efficiency of fine motor skill (e.g., Lyons et al., 2013), it has been shown to impact perceptual-cognitive skills associated with making anticipatory judgments (for review, see Schapschröer et al., 2016). Debate remains as to whether physiological load affects perceptual-cognitive skills in a positive (Royal et al., 2006) or negative manner (Alder et al., 2019; Casanova et al., 2013).

Casanova et al (2013) reported that the anticipatory accuracy of skilled and less-skilled soccer players reduced significantly when experiencing high levels of physical load. Interestingly, for the skilled players the reduction in accuracy was accompanied by a reduced number of fixations of greater duration to fewer locations, whereas the less-skilled players utilised more fixations of shorter duration to a greater number of locations. Although further visual search analysis provided little extra insight into the skill-based differences, it was clear that both changes in visual search behaviour were detrimental to performance. Nieuwenhuys and Oudejans (2012; 2017) *Integrated Model of Anxiety and Perceptual-Motor Performance* (2012) provides a framework to couch an exploration of the impact of various sources of load, such as physical load, on anticipatory performance of skilled athletes. Although this framework was developed with loads associated with cognitive anxiety in mind, Alder et al. (2019) found it useful for exploring the impact of physical load on anticipation performance and enabled the discovery that physical load affected performance effectiveness (i.e. outcome of a task) and efficiency (i.e. visual search behaviour and mental effort) in a similar way to anxiety.

In line with the findings of Casanova et al. (2013), the model implies that additional load leads to a reduction in the ability of an athlete to remain focused on task-relevant stimuli. Instead, there is an increased tendency to either be drawn towards threatening stimuli (Wilson, Wood & Vine, 2009), perhaps reflected in less fixations upon fewer locations as was the case with Casanova et al.'s (2013) skilled players, or become distracted by task-irrelevant cues, possibly resulting in more fixations to an increased number of locations as per the less-skilled players (see Alder et al., 2019 for similar findings with skilled badminton players). Both these adaptions to visual search behaviour have been shown to lead to reduction in the ability to anticipate upcoming actions.

In contrast, Royal et al. (2006) reported that experiencing "very high" physical load caused elite water polo players to make better decisions compared to conditions in which load was lighter, and attributed the finding to the higher load being most representative of the demands of competition. In this case, the extra effort that might have been allocated to the task in response to the advanced physical load may have promoted a goal-directed focus of attention, akin to competition, that enabled a more effective extraction and interpretation of information (Eysenck et al., 2007). Unfortunately, without ratings of mental effort or visual search data in the paper by Royal et al. (2006) this is mere supposition. Further research is required to clarify the impact of physiological load on visual search behaviour and anticipation in a team-based sport, such as soccer.

A second known additional load that has been shown to negatively impact soccer performance is mental load (for review, see Smith et al., 2018). Soccer players must remain focused for extended periods, continuously scanning the everchanging environment and identifying relevant information to make effective decisions under severe time constraints and pressure (Coutts, 2016). These perceptual-cognitive demands likely induce increasing levels of mental load during competition (Walsh, 2014). Mental load has been shown to lead to a reduction in technical (Smith et al., 2016) and tactical performance (Coutinho et al., 2017; Kunrath et al., 2020), a reduction in physical proficiency (Boksem et al., 2005), impaired peripheral perception (Kunrath et al., 2020), and a reduction in decision time and accuracy (Smith et al., 2016). While more fundamental research has suggested that mental load results in poor use of visual cues for action preparation (Boksem et al., 2006), the impact of mental load on visual search behaviours in sport is less clear. For example, Smith et al. (2016) describe how within a soccer-based decision-making task, completing 30 minutes of mentally challenging activity, in this case the Stroop task, increased subjective ratings of mental effort and impaired the speed and accuracy of decision making. However, these changes where accompanied by small non-significant changes in visual search. Smith et al. (2016) postulated that the small sample size made it difficult to determine whether the changes in visual search behaviour underpinned the effect of mental load on decision making. It remains that research is needed to examine the impact of mental load on the visual search behaviours of skilled athletes.

As discussed earlier, the Integrated Model by Nieuwenhuys and Oudejans (2012; 2017) further states that to maintain performance levels individuals can increase effort (assign more resources) to compensate for the additional load induced by heightened anxiety. In the case of anticipation, this additional effort might be directed to reinforce efficient attentional strategies, such as maintaining visual search behaviour strategies and/or ensure pertinent information extracted from the performance environment is utilised. However, as indicated by visual search data (Alder et al., 2019; Casanova et al., 2013), it is argued that there is a point at which the load outweighs the attentional resources available to sustain effective goal-directed behaviours (Eysenck et al., 2007). A central tenet of Attentional Control Theory (Eysenck et al., 2007), upon which Nieuwenhuys and Oudejans (2012; 2017) model was based, is that the impact additional load has on performance efficiency and effectiveness becomes greater as task demands increase (Eysenck et al., 2007). It follows, therefore, that the concurrent presence of multiple loads may have a cumulative negative effect on performance. As described above, competitive sport is characterised by the existence of physical and mental loads, which likely accumulate over the time course of competition (Anderson et al., 2016) and frequently co-occur (Helsen & Bultynck, 2004). To our knowledge, no work has studied the impact of combining multiple loads on the mechanisms underpinning skilled perceptual-cognitive performance. This work has the potential to reveal whether the loads common to soccer competition can have an independent and cumulative negative effect on the ability of players to read the game as it unfolds in front of them, which has implications for the design of training programs and also tactical decisions of the coaching team.

The purpose of this study was to build upon previous research to examine the separate impact of physical and mental load on the anticipatory performance of skilled soccer players, and to offer a unique insight in to the combined impact of physical and mental loads. Visual search behaviour and a range of objective and subjective measures of efficiency were assessed to examine the impact of the different types of loads on anticipatory performance. We predicted that response accuracy in the separate physical and mental load conditions would worsen when compared to baseline levels (Casanova et al., 2013; Smith et al., 2016) and coincide with an increase in effort and a change in visual search behaviour (Alder et al., 2019; Boksem et al., 2006; Casanova et al., 2013). Based on research examining the impact of physical and mental load separately, we expected that the combined effect of mental and physical loads would further decrease the capability of skilled players to anticipate an upcoming action, exacerbate the change in visual search behaviour, and increase the perceived mental effort.

Method

Participants

At the point of recruitment, participants completed a playing history questionnaire form which elicited the start age in soccer training and competition, the level of engagement in soccer-related developmental activities, including competition and different types of practice (e.g., deliberate, strength & conditioning, rehabilitation, etc) and estimated volume (hours) for each year engaged in the sport (as per Ford et al., 2010). Sixteen adult male soccer players (*M* age = 22.4 years, *SD* = 2.5) who had accumulated an average of 14 years (*SD* = 3.6) soccer playing experience volunteered for the study. At the time of testing, participants were training at least 6 hours per week. Participants were recruited from four semi-professional teams all of who were playing in competitive leagues within the United Kingdom. Over the course of their developmental years (9 – 16 years) participants had amassed an average of 3750 training hours (*SD* = 423) and played an average of 340 competitive matches (*SD* = 13.2). This is similar to the practice history profiles of skilled soccer players in previous work (Ford et al., 2010). Prior to testing, participants provided informed consent and all procedures were conducted according to the ethical guidelines of the institution of the lead author.

Anticipation test film

The test film was a series of clips of 11 vs 11 patterns of play from a raised side-on third person perspective taken from four professional soccer matches. Immediately prior to the occurrence of a critical moment in the passage of play (e.g., a shot) the clip was occluded; at which point, participants were required to verbally anticipate the action of the ball carrier at the point of occlusion- the lead researcher manually entered the response into an excel sheet. Participants had to choose from the following options; dribble, shoot or pass. On trials in which participants responded with “pass” they were tasked with identifying the specific player who the pass was intended for. A panel of three UEFA (Union of European Football Associations) qualified soccer coaches viewed the clips in their entirety to determine the course of action taken by the ball carrier and if the clip provided a realistic pattern of play. Only clips that had 100 % agreement were used in the study (as per Casanova et al., 2013; Roca et al., 2012; 2013).

In total 80 clips were chosen and edited (Adobe Premier Pro Editing Software, Version CS5, San Jose, USA) into four 20 clip test films. All test films contained clips from each match and a balance of outcomes (i.e. n = 108 of each outcome), each clip was shown once. Clips began with a black screen for 2,000 ms containing white text identifying the trial number (e.g. "TRIAL 1). At 2,000 ms, another black screen showed white text of a "3, 2, 1" countdown that lasted 2,000 ms. At 4,000 ms a red dot appeared on a black background for 1,000 ms to highlight the location of the ball for the forthcoming clip to allow participants to locate the ball from the beginning of the clip thus limiting the search for the ball in the early frames of the clip (as per North & Williams 2008; Roca et al., 2011). At 5,000 ms, a still picture of the initial video frame of the clip action was shown for 500 ms. The clip then played and lasted for a mean of 4,730 ms (SD = 130). Upon occlusion, a black screen with the word "RESPOND" was displayed in white writing for 2,000 ms. No player took longer than the maximum 2,000 ms to provide a response. Each anticipation test film took approximately ten minutes to complete across each of the four conditions described in the Procedure section below. The anticipation test films were back projected onto a two-dimensional screen (size: 2.74 m high × 3.66 m wide; Draper, USA) and participants stood approx. two metres from the screen.

Measures

Response accuracy (RA). RA was recorded on each trial. A trial was deemed correct if the verbal response matched the action of the ball carrier. On trials in which pass was selected as the option, it was only deemed correct if the player the participant identified as being the receiver was correct. Percentage of correct responses per 20 clip test film was calculated as the dependent measure, of RA. Prior to beginning each condition, participants completed four familiarisation trials in which they undertook the same process as in the test and were given the opportunity to ask any questions. The familiarisation trials were not used in any of the test films.

Rating Scale of Mental Effort (RSME; Zijlstra, 1993). RSME was used to assess perceived *cognitive* effort at specific points during the experiment. The scale requires participants to mark a point on a 0 to 150 scale, with 0 indicating "Absolutely no effort", to rate the amount of mental effort required to complete a task. After each condition, participants registered their RSME. The measure was explained to the participants after the familiarisation trials and they were given the opportunity to ask any questions.

Rating of Perceived Exertion scale (RPE; Borg, 2000). RPE was used to assess perceived *physical* effort. The scale requires participants to specify a point on a 6 to 20 scale, with 19 indicating "Very, very hard", to rate the amount of physical effort required to complete a task. Following each condition, participants registered their RPE. The measure was explained alongside the RSME after the familiarisation trials.

Heart Rate (HR). HR was monitored at the end of every minute throughout each condition by a Polar Heart Rate Monitor (M400). The average HR across the condition was established and then computed to be % of HR max as per the Fox method (220 – age; Fox, Naughton & Haskell, 1971).[1]

Visual search behaviours. Visual search behaviours were recorded in all four decision-making tests using a mobile eye-tracking system (Tobii Pro Glasses 2, Tobii Group, Karlsrovägen 2D, Sweden). The head-mounted, binocular system computes point of gaze within a scene through calculation of the vector between the pupil and cornea. The system was calibrated using a still image taken from one of the trials and was consistent throughout each testing condition. Calibration of the eye tracker never took longer than two minutes. Eye movement data were recorded at 20 frames per second and analysed frame by frame using video-editing software (Adobe Premier Pro Video Editing Software, Version CS 5, San Jose, USA). Two gaze measures were calculated per trial: number of fixations and fixation duration (Abernethy & Russell, 1987; Alder et al., 2014).[2] A fixation was defined as gaze remaining within three degrees of visual angle of a location or moving object for a minimum duration of 120 ms (Vickers, 1996).

Procedure

The experiment consisted of a baseline condition followed by three treatment conditions: physical load, mental load, and combined physical and mental load. The three treatment conditions were counterbalanced across participants to control for order effects. The testing sessions for each condition were scheduled seven days apart. At the start of each test session, the test procedure was explained in detail to participants before they were fitted with a HR monitor and completed a 5-minute warm up at 10 km/h on a treadmill. Immediately prior to each anticipation test, participants were fitted with the eye tracker and positioned in front of

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[1] The Fox method has come under criticism due to only considering an individual's age; however, it was deemed an acceptable method in this current study because of the within-subject design adopted.
[2] The location and duration of final fixation was collected and analyzed; however, upon inspection of the data, there were no between condition differences in this data set. Therefore, this variable is not included herein so as to reduce the length and complexity of the results.

the screen to complete a 5-point calibration using a still image of one of the test clips (which was not used in any of the tests).

Baseline condition. Following calibration of the eye tracker, participants completed the four familiarisation trials, after which the calibration of the eye tracker was checked and minor adjustments were made, if needed. Participants then completed the 20-trial anticipation test without interruption. The baseline condition lasted approximately 20 minutes.

Physical load condition. After completing their warm-up, participants were taken through a modified version of the soccer specific Drust running protocol (Drust et al., 2000), which was developed to mimic activity patterns experienced in soccer match on a motorized treadmill. Participants completed 15 blocks of activity with each block containing; 80 seconds jogging (12 km/h) followed by 20 seconds sprinting (20 km/h) and 20 seconds walking (4 km/h). Following the running protocol, participants were fitted eye tracker which was then calibrated and they took part in the anticipation test. The physical load protocol lasted 30 minutes and participants covered approximately 6 km. Total time for the physical load condition was approximately 40 minutes.

Mental load condition. The mental load protocol consisted of an approximately 30-minute Stoop test (Stroop, 1935). Participants were presented with the name of a colour in a coloured font on a large screen (as per anticipation test) and were tasked with verbalising the printed word and not the colour of the font. For example, if a word reads 'green' but is printed in blue, correct answer would be green. The word was presented for two seconds before automatically changing to the next word regardless of whether the participant gave a response. The test contained 100 trials that were separated into five blocks of twenty trials with a 30 second break in-between blocks (as per Smith et al., 2016). Immediately after the mental load protocol, participants were fitted with the eye tracker before completing the anticipation test. Total time for the mental load condition was approximately 40 minutes.

Combined load condition. After completing their warm-up, participants were taken through the modified Drust protocol whilst completing the 100 trial Stroop test. Participants completed 25 trials of the Stroop test after 7.5, 15, 22.5 and 30 minutes of the Drust protocol (as per Casanova et al., 2013). As per the other testing conditions the screen was placed approximately two metres from the participant. After every five blocks of the Drust, HR was taken. Immediately after the combined load protocol participants were fitted with the eye tracker before completing the anticipation test. Total time for the combined load condition was approximately 40 minutes.

Data Analysis

One-way ANOVAs were conducted to compare effects of Condition (Baseline, Physical, Mental, Combination) on RA, the three measures of load (i.e., HR, RSME & RPE), and the two measures of visual search (number of fixations & mean duration of fixations). Intra-reliability observer checks were conducted on the visual search data using the test-retest method (Thomas, Nelson, & Silverman, 2005), with the data from participant 2 (98% reliability), participant 4 (94 % reliability) and participant 6 (97 % reliability) being re-analysed and shown to be reliable. Greenhouse–Geisser procedures were used to correct for violations of the sphericity assumption. Effect sizes were reported as partial eta squared (η_p^2). Any significant main effects were followed up using Bonferroni-corrected pairwise comparisons. The alpha level was set at $p < .05$. Table 1 presents statistics for all follow up comparisons.

Results

Response Accuracy. (RA): There was a significant main effect of Condition, F (3, 56) = 15.23, $P < .01$, $\eta_p^2 = .58$. RA in the Baseline condition (*M* = 78.2 %, *SD* = 9.1) was significantly greater than that in the Mental load (*M* = 60.6 %, *SD* = 7.7), Physical load (*M* = 59.4 %, *SD* = 14.12) and Combined load (*M* = 45.6 %, *SD* = 17.5) conditions (see Figure 1). RA in the Combined load condition was significantly lower than that in the Mental load and the Physical load conditions, which did not differ significantly.

Heart Rate (HR). There was a significant main effect of Condition, *F* (3, 56) = 262.38, $P < .01$, $\eta_p^2 = .96$, with HR in the Physical load (*M* = 82.75 $\%_{HRmax}$, *SD* = 9.23) and Combined load condition (*M* = 82.42 $\%_{HRmax}$, *SD* = 6.99) greater than that in the Baseline (*M* = 30.12 $\%_{HRmax}$, *SD* = 5.51) and Mental load (*M* = 30.00 $\%_{HRmax}$, *SD* = 5.62) conditions (see Figure 2). There was neither a significant difference in HR between Physical load and Combined load conditions, nor between Baseline and Mental load conditions.

Rating of Perceived Exertion (RPE). There was a significant main effect of Condition, *F* (3, 56) = 2508.11, $P < .01$, $\eta_p^2 = .99$. RPE in the Physical load (*M* = 93.75, *SD* = 5.28) and Combined load conditions (*M* = 97.50, *SD* = 2.61) were significantly greater than that in the Baseline (*M* = 11.67, *SD* = 2.47) and Mental load (*M* = 12.27, *SD* = 1.46) conditions (see Figure 2). There was neither a significant difference in RPE between Physical load and Combined load conditions, nor between Baseline and Mental load conditions.

Rating Scale for Mental Effort (RSME). There was a significant main effect of Condition, *F* (3, 56) = 46.93, $P < .01$, $\eta_p^2 = .81$, with RSME in the Mental load (*M* = 43.08, *SD* = 10.67) and Combined load conditions (*M* = 61.25, *SD* = 7.06) being greater than those in the Baseline (*M* = 32.83, *SD* = 11.34) and Physical load (*M* = 21.17, *SD* = 11.89) conditions (see

Figure 2). There was also a significant difference between the Mental load and Combined load conditions. There were however no significant differences in RSME between Baseline and Physical load condition.

Number of fixations. There was a significant main effect of Condition, F (3, 56) = 21.62, $P < .01$, $\eta_p^2 = .66$. The number of fixations in the Baseline condition was significantly lower (M = 4.95, SD = 1.24) than those in the Mental load (M = 7.41, SD = 3.03), Physical load (M = 7.11, SD = 2.25) and Combined load (M = 8.96, SD = 3.55) conditions (see Figure 3). In addition, the number of fixations was significantly greater in the Combined load condition than those in both the Mental load and the Physical load conditions, which did not differ significantly.

Duration of fixations. The main effect of Condition was non-significant, F (3, 56) = 1.27, $P = .29$, $\eta_p^2 = .06$ (see Figure 3).

Discussion

Research examining the impact of additional loads on anticipatory performance has primarily presented different types of load in isolation (e.g. Casanova et al., 2013; Smith et al., 2016). Therefore, an aim of the current study was to examine the impact of combining two common sources of additional load, physical and mental load, on the anticipatory performance of skilled soccer players. Moreover, work examining the separate impact of these additional loads on anticipatory performance has produced conflicting results (e.g. Royal et al., 2006; Casanova et al., 2013; Smith et al., 2016). Therefore, the current study also examined the separate impact of physical and mental load on anticipatory performance, and measured mechanisms underpinning anticipation to gain insight into the occurrence or absence of effects. It was predicted that when presented with physical and mental load in isolation- anticipatory skill would reduce, there would be a change in visual search behaviour and an increase in mental effort when compared to baseline levels. When physical and mental load were combined it was predicted that these negative effects would be further exacerbated due to the accumulative increase in load when compared to the load free condition (e.g. baseline) and when the loads were presented independently.

Data from the separate load conditions suggest that additional load, whether it is physical or mental, has the potential to negatively impact anticipation accuracy in soccer. The findings from the physical load condition supported the work in soccer by Casanova et al. (2013) but contradicted the findings within the “very high” physical load water polo context presented in Royal et al. (2006), while the findings regarding mental load, supported the majority of research in that respective area (Smith et al., 2018). Accompanying the reduction in anticipatory accuracy, the visual search behaviour changed similarly in both the physical and mental load conditions, with an increase in the number of fixations. An increase in the number of fixations might reflect difficulties in identifying the information rich areas of the display upon which to fixate, possibly due to the similar reduction in available attentional resources caused by the two conditions. Regardless, this builds on previous null findings in the mental load literature where a smaller sample size than the current study may have contained the findings (Smith et al., 2016). However, the findings in the physical load condition somewhat contradicts the study by Casanova et al. (2013) who found that physical load decreased, rather than increased, the number of fixations made by skilled players. In the current study, the footage for the task was filmed from an aerial perspective at the side of the pitch, whereas the footage in the Casanova et al. (2013) paper was filmed from high up behind the defending team's goal. These subtle differences between the viewing perspectives used in the two studies may explain the differences in visual search behaviour (Mann et al., 2009) in response to physical load. In both cases, the viewing perspective was different than the perspective experienced by players in a game. Therefore, the finding that physical, and mental, load causes a change in visual search behaviour, which is associated with reduced anticipatory performance, seems more important than the direction of the change in itself. It is a challenge for future research to design representative tasks that afford the study of the specific affect additional load has on visual search (Dicks, Davids & Button, 2009; McGuckian, Cole & Pepping, 2018).

As described, the imposition of an additional load, whether it be mental or physical, had a negative effect on the accuracy of anticipatory judgements in soccer. Interestingly though, the different types of load appear to only impact the mechanisms associated with that specific load. While heart rate and ratings of perceived exertion increased in the physical load condition this was not accompanied with an increase in ratings of mental effort, and vice versa in the mental load condition. The findings from the physical load condition somewhat contradicts *Attentional Control Theory* (Eysenck et al., 2007) and Nieuwenhuys & Oudejans's (2012; 2017) *Integrated Model*, which would predict that under physical load individuals would increase effort to maintain effective visual search behaviour and, subsequently, performance. This was shown in the study by Alder et al. (2019), whereby, as the physical demand increased so too did the players self-report ratings of mental effort. A potential explanation for the lack of increase in mental effort in the physical load condition may be the third person perspective utilised in the anticipation task, as previously outlined. The skilled participants may not have been able to implement self-control strategies, such as goal-directed attention focusing, which they would typically employ in a more representative task (e.g. Roca et al., 2013). The suggestion, therefore, would be that the increase in mental effort in the mental load condition was not due to efforts to maintain performance but rather, more simply, it was just a by-product of the mentally demanding Stroop task. This explanation is supported by the finding that players changed their visual search behaviour (higher number of fixations) in both the physical and mental load conditions. Participants appeared unable to, or think it appropriate, maintain the visual search behaviour by increasing mental effort to help inform anticipatory judgements (Alder et al., 2019).

Findings from the combined condition, in which physical and mental load was applied to players concurrently, supported our hypothesis. Anticipatory judgements were less accurate when compared to the (unloaded) baseline condition, and, crucially, when mental and physical load were applied independently. This reduction in the accuracy of anticipatory skill followed reports of physical exertion that mirrored, but did not exceed, the perceived exertion reported by players in the physical load conditions. However, the mental effort reported in the combined condition did exceed those reported in the mental load condition. This potentially suggests that players did increase mental effort in the combined condition, over and above the efforts required on the Stroop task, in an attempt to maintain goal-directed attentional strategies and protect against a decrement in performance (Eysenck et al., 2007). Despite these efforts it appears the load in the combined condition was such that participants failed to remain goal-directed in their attentional control and instead became more susceptible to distracting and non-relevant stimuli. Partial support for this is presented in the objective visual search data as the heighted number of fixations observed when load was applied in isolation was exacerbated by the concurrent application of mental and physical load. Therefore, the further change in visual search behaviour may underpin the observed reduction in response accuracy. It suggests that even with the recruitment of additional mental effort, the dual-load further undermined players capability to identify, extract or process information that would allow them to effectively judge the course of action (Alder et al., 2019). This interpretation of the findings does raise the question of why the players would increase mental effort to maintain performance in the combined condition but not in the independent load conditions? Future research is required to examine this question and it may be that the use of retrospective self-reports is not a valid enough measure of mental effort, and, therefore, the current findings and interpretations should be viewed with caution.

In terms of limitations of the piece, the current study design did not counterbalance all conditions, with the baseline condition always completed first. This may have led to an order effect although the differences between the experimental conditions cannot be attributed to this. Another limitation of the project is that physical and mental load were induced using experimental approaches that lack high levels of ecological validity (Schapschröer et al., 2016). Moreover, the current work did not examine the impact of making sport-specific decisions whilst completing sport-specific physical movements. Therefore, the current study may not capture the full processing demands of the performance environment in soccer. Future research should try to design an experiment that allows for test trials to be completed intermittently across load conditions that more closely replicate soccer competition. As technology improves there may be ways to analyse technical, physical and perceptual-cognitive skills in actual competition, whilst also monitoring physical and mental load. This will enhance the ecological validity but may impact the experimental control and the subsequent explanation of the findings. The variety of methods used in this topic area to induce physical and mental load, and also for testing perceptual-cognitive skills, creates difficulties when attempting to compare findings across studies (Schapschröer et al. 2016; Smith et al. 2018). A more systematic approach to examining the impact of various levels of physical and mental load on performance in sport is required in future research to facilitate comparisons across studies. Furthermore, future research should consider other factors that may contribute to the negative impact of mental and physical load on perceptual-cognitive skills and performance. Fatigue has been shown to be associated with a broad range of side effects, such as decreased motivation and alertness and changes in mood (Dantzer et al., 2014). Research is required to investigate these potentially moderating factors of physical and mental load of sport performance.

From a practical perspective, this work suggests that the loads common to sporting competition can have an independent and cumulative negative effect on the ability of players to ‘read the game’. As such, future work should look to understand the extent of the demands on players during competition, in order to be better placed to design interventions to mitigate against the negative effects. To date there has been considerable work that has captured the type of physical load that can be placed upon players (Henderson et al., 2015); however, less is known about the mental load of players in invasion games, particularly with regard to the demands of decision-making.

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