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Think, see, do: Executive function, visual attention, and soccer penalty performance

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Abstract

Executive function and visual attention have been reported as important for sport performance in high-pressure situations, yet the interaction between these factors is not fully understood despite joint theoretical links to Attentional Control Theory-Sport. Specifically, whether visual attention (i.e., quiet eye, search rate, and fixations to key locations) mediates the relationship between executive function (i.e., shifting, inhibition, and updating) and soccer penalty performance under pressure is still unknown. An experimental between-subjects design with random assignment to low- and high-pressure conditions was used. Ninety-five participants (M_{age} = 25.07, SD_{age} = 7.50 years, 58 males) with a range of training and competitive soccer experience (M_{years} = 6.09, SD_{years} = 7.82), completed measures of situational stress, physical activity, athletic expertise, and tasks of executive function, before completing a soccer penalty task while visual attention was recorded via a mobile eye-tracker. Between-subjects ANCOVA showed no significant differences between the pressure conditions in visual attention or soccer penalty performance, so subsequent analyses were collapsed across all participants. Mediation revealed that the effect of inhibition on soccer penalty performance was significantly mediated by quiet eye duration, search rate, and the number of fixations toward the goal. Also, the effect of updating on soccer penalty performance was significantly mediated by quiet eye duration and location, and the number of fixations toward the goal. These results are the first to suggest that executive function (inhibition and updating) and visual attention (quiet eye duration and location, fixations toward the goal, and search rate) combine to enhance soccer penalty performance.

Key Words: Inhibition; Shifting; Updating; Visual Search; Sport Performance

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Given the prevalence of pressurised moments, sport provides an optimal environment for examining divergent performance under pressure. Pressure can be defined as any situation containing a factor(s) that enhances the need to perform well (e.g., audience presence, competition, performance-contingent rewards and punishments, and ego relevance; Baumeister & Showers, 1986). Attentional Control Theory (Eysenck et al., 2007) suggests attention suffers under pressure due to heightened anxiety or stress, resulting in poorer performance. However, a recent theoretical update, Attentional Control Theory-Sport (ACT-S; Eysenck & Wilson, 2016), suggests personal interpretations of a pressurised situation govern individual stress responses (i.e., positive or negative). Theoretically, ACT-S adopts the cognitive attention measures (i.e., shifting, inhibition, and updating) proposed by Attentional Control Theory, but contextualises these processes to sport performance. It has become commonplace to test ACT-S assumptions using visual attention measures (e.g., the quiet eye; Vickers, 2007), leaving the cognitive processes under-examined. Little is known about how cognitive processes, referred to as executive function, influence visual attention and subsequent sport performance (Vaughan & Edwards, 2020). The present study is the first to examine the potential mediating role of visual attention on the executive function and sport performance relationship.

Attentional Control Theory-Sport

Attentional Control Theory (Eysenck et al., 2007; see Figure 1) suggests that the ability to control attention is influenced by two systems proposed by Corbetta and Shulman (2002). The goal-directed system (utilising a ‘top-down’ approach), which is located within the intraparietal and superior frontal cortex, is primarily influenced by previous knowledge, current expectations, and goals. The stimulus-driven system (utilising a ‘bottom-up’ approach) is located within the temporoparietal and inferior frontal cortex and is specialised in detecting salient or conspicuous stimuli (Corbetta & Shulman, 2002). Anxiety or stress may cause over-activation of the stimulus-driven system (i.e., increased vigilance towards task-irrelevant and/or threatening stimuli) at the expense of the more efficient goal-directed system, which may negatively affect performance despite the use of compensatory strategies (e.g., mental effort; see Eysenck et al., 2007, for an overview of Attentional Control Theory). Attentional Control Theory assumes that when pressurised or stressful situations lead to increased anxiety, processing efficiency (i.e., the relationship between performance quality and the resources used to complete a task) is impaired, but not always processing effectiveness (i.e., performance quality). Recruitment of additional resources such as mental effort can maintain effectiveness, but limit efficiency.

Another key assumption, and the focus of the present study, is that negative task performance under pressure may arise due to inefficiency of the central executive (i.e., inhibition, shifting, and updating; Miyake et al., 2000). To date, limited research in sport supports a link between the central executive (i.e., executive functions) and performance under pressure. After inhibition training, Ducrocq et al. (2016) found superior performance on a pressurised tennis task in the trained group compared to a group that did not receive inhibition training. However, Attentional Control Theory did not consider the antecedents of anxiety (e.g., motivation), which is resolved in the recent theoretical update ACT-S (Eysenck & Wilson, 2016).

One key modification within ACT-S (see Figure 1) is that the antecedents of anxiety or stress experienced under pressure vary between individuals and depend upon personal interpretation of the situation. Specifically, ACT-S suggests that the relationship between pressure and performance is contingent on personal feedback concerning previous and optimal performance (Eysenck & Wilson, 2016). Personal assessment of feedback in turn effects the perception of threat, and subsequent feelings of anxiety (Harris et al., 2019). These feedback loops include personal cognitive biases, perceptions of the cost, probability of failure, and motivation levels (Eysenck & Wilson, 2016). In line with Attentional Control Theory and ACT-S, research has reported that performance can sometimes be enhanced under pressure (e.g., 'clutch' performance; Otten, 2009) despite the potential room for substandard performance given the high-pressure context (Baumeister, 1984). Positive interpretations of a pressurised situation may facilitate a balance between the attentional systems (i.e., goal-directed and stimulus-driven systems) allowing attention to be directed to task-related stimuli and potential threatening stimuli simultaneously. As a result, it is plausible that executive functions (i.e., shifting, inhibition, and updating) may operate more efficiently, combatting the potentially negative effect of anxiety and stress experienced under pressure, allowing for subsequent visual attention and performance to be optimised.

Executive Function and Sport

Both Attentional Control Theory and ACT-S propose a lower-order model of executive functions (i.e., shifting, inhibition, and updating) which are believed to be interrelated, yet distinct (Miyake et al., 2000). Shifting involves a 'shift' of attention, often between tasks, operations, or mental sets (Miyake et al., 2000), and is typically housed under 'selective attention' (Wendt et al., 2017). Previous research has utilised a Flanker task to capture the shifting function (e.g., Krenn et al., 2018). A Flanker task may be particularly applicable in the present study, given the measurement of visual attention, as the Flanker task requires a shift of visuospatial attention from distracting 'flanker' stimuli, toward task-related centralised stimuli. Greater visual shifting in the Flanker task (i.e., propensity to shift from distractor stimuli and attend to central target arrows) may relate to greater visual shifting in the soccer penalty task (i.e., tendency to shift from distractor stimuli [the goalkeeper] and attend to goal-related stimuli [the goal]).

Inhibition is the ability to withhold a dominant/prepotent response that is no longer task appropriate (Miyake et al., 2000). Popular inhibition paradigms include the Go/No-Go paradigm and the Stop Signal paradigm. Go/No-Go paradigms assess automatic inhibition as certain stimuli are associated with a ‘go’ response and alternate stimuli are associated with a ‘no-go’ response. Stop Signal paradigms require controlled responses, as all stimuli are associated with a ‘go’ response. Following certain trials, a ‘stop’ signal follows stimulus presentation rendering said trial a ‘no-go’ trial (Verbruggen & Logan, 2008). The Parametric Go/No-Go task (Langenecker et al., 2007) may require both automatic and controlled responses. Like a typical Go/No-Go task, the Parametric Go/No-Go task associates certain stimuli with a ‘go’ response and other stimuli with a ‘no-go’ response. However, the task also contains the rule that target stimuli (i.e., ‘go’ response stimuli) become non-target stimuli (i.e., ‘no-go’ response stimuli) if that same target is presented consecutively. This task is relevant to the current soccer penalty task as it may require automatic (i.e., inhibition of typically threatening ‘no-go’ stimuli [the goalkeeper]) and controlled (i.e., adapting behaviour based on goalkeeper movement) inhibition responses.

Updating is linked to working-memory and involves the processing of new information in relation to old information (Miyake et al., 2000). Superior updating allows for optimal manipulation of information, ensuring task-relevant information is utilised and task-irrelevant information is removed (Miyake et al., 2000). Updating is typically measured using an n-back task, which has been utilised with athlete samples (e.g., Krenn et al., 2018). Greater working-memory (i.e., updating) has been associated with an improved ability to maintain goal-directed attention (Wood et al., 2016). In a review of working-memory and attentional control across expertise, Furley and Wood (2016) suggest that superior working-memory may aid goal-directed attention by allowing an individual to avoid distraction and resolve interference. In the first experiment of a two-part study, Furley and Memmert (2012) found that basketball players with greater working-memory performed better on a sport-specific decision making task while simultaneously blocking out distracting auditory stimuli. In experiment two, greater working-memory was associated with better interference resolving ability as high working-memory individuals more often adjusted their decisions to task demands instead of blindly following task inappropriate instructions. Given that greater updating has been linked to superior goal-directed attentional control, it may be highly relevant for a soccer penalty task. Superior updating may allow for more attention allocation toward goal-directed stimuli (i.e., the goal) and less attention to the potentially threatening stimuli (i.e., the goalkeeper).

Poorer shifting, inhibition, and updating performance has been associated with increased distractibility (Eysenck & Wilson, 2016). Indeed, elite athlete accounts have indicated that 25.9% of thoughts under high-pressure relate to distraction (Oudejans et al., 2011), which may relate to inhibition as research has noted that resisting distractor interference is reliant upon the inhibition function (Friedman & Miyake, 2004). The relevance of these executive functions for sport performance has also been empirically tested (e.g., Verburgh et al., 2014; Vestberg et al., 2017). Vestberg et al. (2017) found that higher division (i.e., Swedish 1st division) youth soccer players displayed significantly greater shifting ability (indexed with a Color-Word Interference Test) compared to lower division (i.e., Swedish 2nd and 3rd division) youth soccer players. Vestberg et al. (2017) also found that improved updating (assessed via a modified n-back task) performance was associated with more goal contributions (i.e., goals and assists) over the subsequent two seasons in elite youth soccer players. Finally, Verburgh and colleagues (2014) found elite youth soccer players showed greater inhibition (measured via a Stop Signal Task) compared to age-matched amateur youth soccer players.

Research suggests that the relationship between executive function and sport performance may highly relate to expertise (e.g., Verburgh et al., 2014; Vestberg et al., 2017). For example, Hagyard et al. (2021) reported that expertise was related to inhibition (measured via a Stop Signal Task) both cross-sectionally and longitudinally over a 16-week period. Therefore, expertise should be controlled for in any analyses not explicitly examining group differences (i.e., elite vs. novice groups) in order to ensure that results are not attributable to expertise differences. Physical activity can also influence executive function (e.g., via increases in brain plasticity; Erickson et al., 2015). Elite athletes undergo intense and extensive training in which they often exhibit high levels of physical fitness, motor control, and cognitive ability (Diamond & Ling, 2016). Huijgen et al. (2015) examined the influence of physical training hours on executive function. Results revealed elite youth soccer players had significantly higher physical training hours and composite scores on tasks of inhibition, shifting, and updating compared to sub-elite youth soccer players. However, with physical training hours entered as a covariate, differences between the groups on executive function, while still significant, were reduced. This suggests differences in executive function may have been in part driven by physical training hours, supporting the inclusion of physical activity as a covariate. Despite executive function being linked to expertise and physical activity, research rarely controls for the influence of these variables.

Visual Attention and Sport

Visual attention is commonly used to examine the assumptions of ACT-S with studies typically using a mobile eye-tracking device to obtain visual attention measures (e.g., Ducrocq et al., 2016). In a recent review, Kredel et al. (2017) noted the increase in eye-tracking technology over recent decades. Popular metrics of visual attention include quiet eye duration and location (see Mann et al., 2007 and Lebeau et al., 2016, for reviews) and search rate (calculated with the number and duration of fixations). Meta-analytic results from Mann et al. (2007) revealed that experts displayed significantly fewer fixations, longer fixation durations, and longer quiet eye durations compared to novices indicating that differences in visual attention may influence successful performance. In an updated meta-analysis, Klostermann and Moeinirad (2020) found expert-novice differences in quiet eye duration and location were still apparent, but differences in the number of and duration of fixations were now less consistent.

Quiet eye duration has been defined as the length (in milliseconds) of the final fixation before initiating a critical movement and a period where task-relevant information is processed (Vickers, 2007). An extended quiet eye duration has been linked to more successful performance in basketball (Wilson, Vine, & Wood, 2009), golf putting (Moore et al., 2013), and soccer penalties (Wood & Wilson, 2011) indicating its role as a marker of goal-directed attentional control (Wilson, Vine, & Wood, 2009). Quiet eye location refers to the visual target of the final fixation (Vickers, 2007). Research examining the quiet eye location in soccer penalty kicks is mixed potentially due to the various techniques that are utilised in soccer penalties (Kuhn, 1988). Wood and Wilson (2010b) reported that the quiet eye location in a soccer penalty kick was unrelated to technique (i.e., keeper-dependent, keeper-independent, and opposite independent), yet was important for performance. Search rate refers to the ability to maintain attention upon goal-directed stimuli. When low (i.e., fewer fixations of longer duration), the search rate is indicative of optimal goal-directed attention in certain tasks (Wilson, Vine, & Wood, 2009). For example, low stress individuals have been shown to exhibit low search rates in a pressurised soccer penalty task (Brimmell et al., 2019) and a dart throwing task (Nibbeling et al., 2012), typically indicative of superior visual attention.

The ACT-S contends that negative interpretations of pressure induce anxiety or stress and subsequently increase attention allocation toward threatening stimuli at the expense of goal-directed stimuli (Eysenck & Wilson 2016). Wood and Wilson (2010a; 2011) noted that, during soccer penalty performance, anxiety related disruptions to attentional control occur far more during the aiming phase (a phase where critical information is extracted for accurate kicks) compared to the execution phase (where attention is typically focused on ensuring adequate foot-ball contact). This suggests that the aiming phase may be more important than the execution phase when studying the impact of anxiety or pressure on visual attention in soccer penalty kicks[1]. Timmis et al. (2018) corroborated this idea reporting that during the final approach to the ball fixations were primarily located toward the ground at an area just in front of the ball (a phenomenon deemed the "anticipatory fixation"), supporting the idea that during execution gaze is located away from the intended striking target.

Examining soccer penalties may directly test the assumptions of ACT-S as clear goal-directed (e.g., the goal) and potentially threatening (e.g., the goalkeeper) stimuli are present. Previous research examining psychophysiological responses (i.e., challenge and threat states) within a soccer penalty task reported that a positive physiological response (i.e., a challenge state) lead to more fixations toward the goal (Brimmell et al., 2019). Also, under low-anxiety conditions, fixations were more distally located within the goal area potentially representing greater goal-directed attention (Wilson, Wood, & Vine, 2009). Finally, Binsch et al. (2010) found that individuals who fixated on the goalkeeper despite being explicitly informed not to look at the goalkeeper (i.e., the "ironic" effect) displayed significantly shorter final fixations (i.e., quiet eye duration) and significantly more centrally located soccer penalty kicks in the "not-keeper" condition when compared to "accurate" and "open-space" conditions. Regarding fixations toward the goalkeeper, research has been less definitive. Wilson, Wood, and Vine (2009) found participants made significantly more fixations to the goalkeeper in a high-anxiety condition compared to a low-anxiety condition. However, a negative psychological response to a high-pressure soccer penalty task did not lead to significantly more fixations toward the goalkeeper (Brimmell et al., 2019). More research is needed to further explore this relationship and to test whether interactions between visual attention (i.e., gaze behaviour) and executive function (i.e., shifting, inhibition, and updating) explain soccer penalty performance.

Executive Function, Visual Attention, and Sport

Research has begun to examine the interplay between executive function, visual attention, and sport performance (e.g., Ducrocq et al., 2017; Wood et al., 2016). Ducrocq et al. (2016) used an inhibition training paradigm to improve visual attention (i.e., first target fixation) and tennis-specific sport performance. Those who underwent inhibition training showed significantly later first target fixation (indicating superior inhibition and visual attention) and greater tennis performance under pressure. Ducrocq et al. (2017) implemented a working-memory training paradigm that, for those within the training group, lead to significantly later quiet eye offset times and improved tennis performance under pressure. Given that executive function has been linked to sport performance (e.g., Vestberg et al., 2017), that training elements of executive function can lead to subsequent improvements in visual attention (e.g., Ducrocq et al., 2016; 2017), and that improved visual attention relates to better soccer penalty kick performance (e.g., Wood & Wilson, 2011), it may be that visual attention mediates the executive function and sport performance relationship (i.e., executive function first impacts visual attention before subsequently affecting sport performance). However, this hypothesis is yet to be examined.

The Present Study

Research has typically utilised visual attention metrics (i.e., quiet eye duration and location, search rate, and fixations to key locations) to test the predictions of ACT-S at different pressure levels. The lack of focus on the executive functions proposed by ACT-S is surprising given their importance within sport performance (e.g., Vestberg et al., 2017). To fill this gap, the present study first aimed to replicate whether different pressure instructions (i.e., low- and high-pressure) lead to differences in visual attention and sport performance

(Wilson, Wood, & Vine, 2009). Second, this study examined the extent to which visual attention (i.e., quiet eye duration and location, search rate, and fixations to key locations) mediated the executive function (i.e., shifting, inhibition, and updating) and sport performance (i.e., soccer penalty) relationship, after controlling for important covariates (i.e., physical activity and expertise).

We offered the first direct test of the relationship between the theoretically proposed executive functions of ACT-S and the typically used visual attention measures in a single sport task. While having theoretical importance for ACT-S, this relationship may also be of interest for sport coaches and practitioners. Specifically, by characterising precisely which executive function and/or visual attention factors are important for sport performance under pressure, findings from the present study can provide target markers for interventions. Based on theory and evidence (e.g., Wilson, Wood, & Vine, 2009), we hypothesised those in the high-pressure condition would display poorer visual attention, and soccer penalty performance compared to the low-pressure condition. Lastly, guided by prior findings (e.g., Ducrocq et al., 2016; 2017) we also hypothesised that executive function (i.e., inhibition, shifting, and updating) would predict soccer penalty performance through the mediator of visual attention (i.e., quiet eye duration and location, search rate, and fixations to key locations).

Method

Participants

Ninety-five participants (58 male; M_{age} = 25.07 ± 7.50 years) with a range of athletic expertise took part in the study (i.e., non-athlete: n = 47, novice: n = 16, amateur: n = 18, and elite: n = 14; based on Swann et al., 2015). Participants received verbal and written study instructions and were tested individually. Participants were allocated randomly to receive either low-pressure or high-pressure instructions (see Procedure for details). Power analysis indicated a sample of 89 participants were needed to detect a moderate indirect effect (per Vaughan & Laborde, 2020) where partial r for all paths = .33, alpha = .05, and power = .80 (MedPower; Kenny 2017).

Measures

Situational Stress

The Stress Rating Questionnaire (SRQ; Edwards et al., 2015) is 5-item self-report measure of situational stress that has previously been used as a manipulation check following pressure instructions (see also Brugnera et al., 2017). Responses are provided on 7-point Likert scales that assess five bipolar dimensions (e.g., calm to nervous) with scores ranging from 1 (e.g., very calm) to 7 (e.g., very nervous). Composite scores on the SRQ are calculated by summing responses on each dimension, such that higher composite scores reflect higher situational stress. The SRQ was used to determine the efficacy of the pressure instructions where differences in SRQ composite scores from baseline to post-manipulation were compared. Composite scores at baseline have been found to significantly correlate with the State-Cognitive Anxiety scale on the State Trait Inventory for Cognitive and Somatic Anxiety (r = .48; Edwards et al., 2015; Ree et al., 2008) supporting its utility as a valid measure of situational stress. Furthermore, the SRQ has demonstrated satisfactory internal consistency with Cronbach's α ranging from .87 to .89 (Brugnera et al., 2017) and α = .92 in the current study.

Physical Activity

The International Physical Activity Scale-Short Form (IPAQ-SF; Booth, 2000) measures physical activity over the preceding seven days. The IPAQ-SF consists of seven items, two measuring vigorous activity, two measuring moderate activity, two measuring walking activity, and one measuring sitting time. For vigorous, moderate, and walking activity one item measures frequency (number of days this activity was completed) and one item measures duration (in minutes). A metabolic equivalent (MET)-minutes per week score was calculated from the activity-based elements (i.e., vigorous, moderate, and walking activity; Hagstromer et al., 2006). Time completing each element by a participant is assigned a score based on the energy requirement in METs. Once all elements are scored, these scores are summed to create a MET-minutes per week score for analyses. The IPAQ-SF has shown high external and construct validity in comparison to the longer format questionnaire (Nigg et al., 2020).

Expertise

Expertise was calculated based on the classification recommendations from Swann et al. (2015). Classification included creating a composite score based on A) individual highest performance standard (e.g., professional athlete), B) success at highest standard (e.g., league titles won), C) experience at that standard (e.g., years at the highest performance level), D) competitiveness of selected sport in residing country (e.g., national sport with high participation levels), and E) global competitiveness of selected sport (e.g., globally recognised sport with high participation levels). Each individual factor (e.g., highest performance level) is assigned a score between zero and four based on criteria outlined in Swann et al. (2015). These scores are then entered into the equation; expertise = [(A + B + C /2) /3] x [(D + E) /2]. The outcome composite score is then used to assign an expertise level (e.g., elite). The framework has been successfully used to distinguish between expertise levels in previous research (Hagyard et al., 2021; Vaughan & Edwards, 2020).

Executive Function

The executive functions examined in the present study comprise a lower-order model of shifting, inhibition, and updating (Miyake et al., 2000). Shifting was measured with the Flanker task (Ridderinkhof et al., 1997) which has displayed acceptable intraclass-correlations (*r* = .66-.74; Hedge et al., 2018). Inhibition was measured using the parametric

Go/No-Go task (Langenecker et al., 2007) which has previously shown acceptable construct and discriminant validity (Votruba & Langenecker, 2013) and test-retest reliability (*r* = .57-.83; Langenecker et al., 2007). Updating was measured using the n-back task (Jaeggi et al., 2010) which has shown acceptable construct validity when compared to alternate measures of updating (*r* = .33-.45; Shelton et al., 2009).

Shifting. The Flanker task involved identifying the direction of a centralised arrow (displayed for 1750ms before timeout) that is ‘flanked’ by distractor arrows that are either congruent (i.e., arrows face the same direction as the target arrow) or incongruent (i.e., arrows face the opposing direction to the target arrow). Participants selected the direction they feel the arrow is facing as quickly and accurately as possible. The outcome measure was based on switch cost (i.e., difference between reaction time on correct congruent trials and correct incongruent trials; Hughes et al., 2014). However, switch costs often fail to capture both latency and accuracy in one measure (Hughes et al., 2014). An inverse efficiency score was calculated to incorporate both latency and accuracy by dividing mean reaction time by mean accuracy for both congruent and incongruent trials. The difference between these scores was then indexed as shifting ability (i.e., incongruent inverse efficiency - congruent inverse efficiency; Hughes et al., 2014).

Inhibition. The Go/No-Go task involved a continuous stream of letters, each displayed for 500ms, a small number of which are targets (i.e., “r” and “s”) while other letters acted as distractor stimuli. This task utilised two levels to assess response inhibition. The first level aimed to build a response tendency and requires participants to respond to all target letters, while ignoring distractor stimuli. The second level assessed inhibition ability based on a contextual rule. The rule being that participants must respond to target stimuli in a non-repeating order (i.e., respond to the “r” target only if the previous target was “s”), while still ignoring distractor stimuli. An inhibition score was calculated using the following equation, ({[(5 x PCTT) + PCIT]/6} /RT) x 100; Votruba & Langenecker, 2013). Where Percentage Correct Target Trials (PCTT) is correct target responses divided by the total possible correct target responses. Percentage Correct Inhibitory Trials (PCIT) is correct inhibitory trials divided by the total possible inhibitory trials and Response Time (RT) is mean response time on correct target trials.

Updating. The n-back task involved the sequential presentation of eight unfamiliar yellow shapes against a black background for 500ms, followed by a 2,500ms interstimulus interval. The n-back task comprised three experimental conditions, each of which were completed twice (e.g., 2 × 2-back). In the 2-back task participants responded to the stimuli if it were the same as the one presented two trials before. The 3-back task required participants to respond if the stimuli were the same as the one presented three trials before. Finally, in the 4-back task participants responded to the stimuli if it were the same as the one presented four trials before. The outcome measure was the quantity of hits minus false alarms averaged over all levels of the task (Jaeggi et al., 2010).

Visual Attention

Visual attention was measured via a lightweight (76 g) binocular mobile eye-tracking device, recording at a spatial resolution of .5˚ and a temporal resolution of 30 Hz (SensoMotoric Instruments PLC., Boston, Massachusetts), connected to a mobile recording device (ETG recording unit 2.0, Samsung Galaxy S4, Samsung Electronics LTD., Surrey, United Kingdom). Before completing the soccer penalty task, a 3-point calibration process was completed to ensure adequate tracking of gaze. Calibration points included a near target (i.e., a soccer ball .5 m from the participant) and a far target (i.e., a researcher 5 m from the participant). Quiet Eye Solutions software was used for offline frame-by-frame analysis (www.quieteyesolutions.com). A fixation was defined as maintenance of gaze within 1˚ of visual angle for at least 120 ms (Vickers, 2007). Five gaze measures were calculated for the aiming phase (i.e., pre-run-up; as in Wood & Wilson, 2011) and included: 1) quiet eye duration, 2) quiet eye location, 3) search rate, 4) number of fixations to the goal, and 5) number of fixations to the goalkeeper.

The quiet eye. The quiet eye duration was defined as the final fixation in ms (where a fixation is the maintenance of gaze within 1° of visual angle for a minimum of 120ms; Vickers, 2007) that began before the initiation of the critical movement (i.e., the run-up; Vickers, 2007). The onset of the quiet eye occurred before initiating this critical movement. The offset of the quiet eye occurred when gaze deviated from the fixation location by 1° of visual angle (Vickers, 2007). Though the quiet eye duration begins before the initiation of the critical movement (i.e., quiet eye onset), the duration can carry on through the remainder of the movement process. In this case the quiet eye duration could carry on from the pre-run up, throughout the run-up, foot-ball contact, and even beyond. Quiet eye location was based on the spatial location of the final fixation (i.e., quiet eye) during the aiming phase (as in Wood et al., 2017). This method involved separating the goal into 12-zones (6-zones in each half of the goal) ranging from 0cm at the centre to 180cm at each respective post. The location was determined using frame-by-frame analysis in Quiet Eye Solutions to deduce the distance of the final fixation from the centre of the goal in cm (i.e., higher scores represent distally located quiet eye fixations whereas lower scores represent centrally located quiet eye fixations; as in Wood et al., 2017).

Fixation data. Search rate involved dividing the total number of fixations by the total duration (in seconds) of fixations (as in Brimmell et al., 2019). The number of fixations to the goal and goalkeeper (deemed key areas in the current task; Brimmell et al., 2019) referred to the sum of fixations toward the goal and goalkeeper, respectively. We opted to record the number of fixations only and not the total or mean duration of fixations as previous research has indicated these variables are highly inter-related. Brimmell et al. (2019) reported a strong correlation between the number and total duration of fixations to the goal (r = .89; p < .01) and between the number and total duration of fixations to the goalkeeper (r = .80; p < .01). Likewise, mean fixation duration was not included as Wilson, Vine, and Wood (2009) reported that both the number of fixations and mean fixation duration were near identical in their influence on performance accuracy and may overlap.

Performance

Frame-by-frame videos from the mobile eye-tracking device's scene camera were used to assess performance in Quiet Eye Solutions software. Performance was based on a single kick of a standard soccer ball (20.57 cm diameter) from a pre-defined penalty spot 5.0 m toward a traditional indoor soccer goal (3.6 m × 1.2 m; B.G. Sports International Ltd., Lancashire, United Kingdom). Each soccer penalty kick was assigned a horizontal 'x' coordinate to determine distance from the centre of the goal and accuracy (in cm; Brimmell et al., 2019). The centre of the goal was defined as the 'origin', with six 30 cm zones either side reaching a maximum 180 cm at either post. Higher scores reflected a more accurate penalty kick placed further away from the goalkeeper (van der Kamp, 2006). Goalkeeper movement (i.e., static), positioning (i.e., central), and posture (i.e., knees bent, and arms out to either side) were all standardised (van der Kamp & Masters, 2008), and the goalkeeper was unfamiliar to participants. Penalties that missed the goal (either over the cross-bar or wide of the goal; n = 13), hit the post (n = 3), the cross-bar (n = 2), or the goalkeeper (where the ball hit the goalkeeper stood at the 'origin'; n = 4), scored zero.

Design and Procedure

The study used an experimental between-subjects design with random allocation to low- and high-pressure conditions (allocation was conducted via the randomiser function using Qualtrics software). Participants provided informed consent, demographic information (e.g., age, sex), and details of sport participation used to calculate expertise (e.g., highest performance standard). Participants then completed the baseline SRQ and the IPAQ-SF. Three executive function tasks were then completed in a counterbalanced order. The tasks were obtained from, and administered via, Inquisit-5 by Millisecond (Millisecond Software LLC., Seattle, Washington) and completed on a MacBook Air 13inch laptop with a 1440 x 900 resolution while the participant was seated. Next, participants received verbal task-instructions, based on their experimental condition (i.e., low- or high-pressure manipulation), adapted from previous research (e.g., Brimmell et al., 2019; Moore et al., 2013). All participants were informed that the task would comprise a single soccer penalty kick and that a goalkeeper would be present. The high-pressure group were also informed that the goalkeeper would be attempting to save the penalty, that there would be a leader board, prizes for top performers, interviews for the poorest performers, and that the soccer penalty was the most important part of the study. Participants then completed their post-manipulation SRQ and were fitted with the mobile eye-tracking device, underwent the calibration procedure, and took a single soccer penalty kick. All elements of the procedure were completed in a specialist sports laboratory and lasted approximately 45 minutes. Finally, participants were thanked and debriefed upon completion.

Data Processing and Statistical Analysis

Data was screened for missing data and multivariate outliers. Means, standard deviations, and zero-order correlations were calculated. Prior to the main analyses, normality was assessed via skewness and kurtosis with all values falling within acceptable range of parametric analyses (i.e., between -2 and 2). The effectiveness of the pressure manipulation instructions at increasing situational stress was assessed using a 2 x 2 mixed ANOVA. A one-way ANCOVA was used to examine whether the low- and high-pressure groups differed in executive function, visual attention, or soccer penalty performance according to the ACT-S, with physical activity and expertise entered as covariates. Non-significant differences on executive function ensures comparability between groups at baseline. To test for mediation (i.e., executive function → visual attention → sport performance) PROCESS custom dialog was used (Hayes, 2018). Fifteen mediation models were completed to satisfy all combinations of the independent variable (i.e., shifting, inhibition, and updating), mediator (i.e., quiet eye duration and location, search rate, number of fixations to the goal, and number of fixations to the goalkeeper), and dependent variable (i.e., performance) with physical activity and expertise entered as covariates. PROCESS custom dialog allows inferences regarding mediation based on the indirect effects shown when using percentile bootstrapped confidence intervals (e.g., a default 5000 bootstrap resampling). When the confidence intervals do not contain zero, mediation can be inferred (Preacher & Hayes, 2008). All statistical analyses were conducted using IBM SPSS statistical software version 25 with an *a priori* alpha level set at $\alpha = .05$ for all relevant analyses (Field, 2013).

Results

Preliminary Analyses

Missing data, which comprised < 1%, was replaced with the item mean using ipsatised item replacement (Tabachnick & Fidell, 2007). Multivariate outliers were determined through examination of the Mahalanobis distance and revealed one multivariate outlier which was removed from subsequent analyses. Means, and standard deviations were then calculated (see Table 1). Zero-order correlations showed that baseline SRQ scores were significantly positively correlated with SRQ post-manipulation scores, and significantly negatively correlated with physical activity and expertise. Post-manipulation SRQ scores were significantly negatively correlated with physical activity, expertise, inhibition, quiet eye duration, and soccer penalty performance, while significantly positively correlated with search rate. Also, physical activity and expertise were significantly positively correlated with quiet eye duration and soccer penalty performance, and significantly negatively correlated with search rate, supporting their inclusion as covariates (see Table 1).

Regarding soccer penalty performance, the only executive function that significantly positively correlated was inhibition. Inhibition was only significantly correlated with updating regarding the executive functions. Shifting was significantly negatively correlated with number of fixations to the goalkeeper. Inhibition was significantly positively correlated with quiet eye duration, number of fixations to the goal, and was significantly negatively correlated with search rate. Updating was significantly positively correlated with number of fixations to the goal and quiet eye location. Quiet eye duration, quiet eye location, and number of fixations to the goal were significantly positively correlated. Search rate was significantly negatively correlated with quiet eye duration, quiet eye location, number of fixations to the goal, and number of fixations to the goalkeeper. Finally, quiet eye duration, quiet eye location, and number of fixations to the goal were significantly positively correlated, while search rate and number of fixations to the goalkeeper were significantly negatively correlated, with soccer penalty performance (see Table 1).

Differences in Low- and High-Pressure

The effect of the pressure manipulation on the dependent variable SRQ differences (i.e., SRQ post-manipulation minus SRQ baseline) was measured using a 2 x 2 mixed ANOVA with Time (baseline vs. post-manipulation) as the within-subject factor and Group (low- vs. high-pressure) as the between-subject factor. There was a significant main effect of Time ($F(1, 93) = 18.66$, $p < .001$, $\eta_p^2 = .17$), however there was no statistically significant main effect of Group ($F(1, 93) = .62$, $p = .435$, $\eta_p^2 = .01$) nor a statistically significant Time x Group interaction ($F(1, 93) = 2.62$, $p = .109$, $\eta_p^2 = .03$). The main effect of time suggested that SRQ scores were significantly higher post manipulation (low-pressure $M = 14.53 \pm 7.03$; high-pressure $M = 16.52 \pm 7.76$) compared to baseline (low-pressure $M = 12.89 \pm 6.55$; high-pressure M = 12.92 ± 6.21) across both low- and high-pressure groups. Despite the non-significant interaction, ANCOVA was conducted to examine whether differences between the pressure conditions manifested in executive function, visual attention or soccer penalty performance.

The results of the ANCOVA revealed no significant differences between the groups (i.e., low- and high-pressure) in inhibition ($F(1, 91) = .01$, $p = .951$, $\eta_p^2 = .00$), shifting ($F(1, 90) = .34$, $p = .559$, $\eta_p^2 = .01$), or updating ($F(1, 91) = .02$, $p = .878$, $\eta_p^2 = .00$), when controlling for physical activity and expertise. This finding confirmed that that the groups were comparable in executive function. The ANCOVA revealed no significant differences between the groups (i.e., low- and high-pressure), when controlling for physical activity and expertise, on measures of quiet eye duration ($F(1, 90) = .90$, $p = .346$, $\eta_p^2 = .01$), quiet eye location ($F(1, 90) = .10$, $p = .749$, $\eta_p^2 = .01$), search rate ($F(1, 91) = .06$, $p = .808$, $\eta_p^2 = .01$), number of fixations to the goal ($F(1, 90) = .07$, $p = .798$, $\eta_p^2 = .01$), number of fixations to the goalkeeper ($F(1, 89) = .14$, $p = .707$, $\eta_p^2 = .01$), and soccer penalty performance ($F(1, 91) = .84$, $p = .364$, $\eta_p^2 = .01$), suggesting that visual attention and soccer penalty performance did not differ between the unique pressure conditions. The ANCOVA revealed no significant differences between the groups (i.e., low- and high-pressure) which suggested that all participants had a similar increase in stress levels from baseline to post-instruction despite the different pressure instructions. Therefore, as groups did not emerge, mediation analyses were collapsed across all participants.

Mediation Analyses

Six significant mediation effects were found (see Tables 2 to 6 for all mediation analyses). Quiet eye duration significantly mediated the inhibition and performance relationship (B = 1.32, 95% CI [0.10, 2.63]). This suggested that greater inhibition may lead to superior soccer penalty performance by facilitating longer quiet eye durations. Search rate significantly mediated the inhibition and performance relationship (*B* = 1.27, 95% CI [0.26, 2.54]). This indicated that greater inhibition may lead to a lower search rate, in turn enhancing soccer penalty performance. The number of fixations to the goal significantly mediated the inhibition and performance relationship (*B* = .82, 95% CI [0.03, 1.73]). This suggested that greater inhibition performance may allow individuals to direct more fixations toward the goal leading to subsequently greater soccer penalty performance. Quiet eye duration significantly mediated the updating and performance relationship (*B* = 3.58, 95% CI [0.66, 7.39]). This implied that greater updating may allow for longer quiet eye durations and superior soccer penalty performance. Quiet eye location significantly mediated the updating and performance relationship (*B* = 4.64, 95% CI [1.63, 8.59]). This suggested that greater updating may allow for more distally located quiet eye locations, in turn allowing for superior soccer penalty kick performance. The number of fixations to the goal significantly mediated the updating and performance relationship (*B* = 2.45, 95% CI [0.32, 5.69]). This suggested that superior updating may allow individuals to direct more fixations toward the goal leading to subsequently greater soccer penalty performance.

Discussion

The current study had two aims. First, to determine whether different pressure instructions (i.e., low- and high-pressure conditions) evoked differences in visual attention and soccer penalty performance as previously found (e.g., Wilson, Wood, & Vine, 2009). Results indicated non-significant differences in reported situational stress between low- and high-pressure groups. This pattern continued as no differences between groups in visual attention or soccer penalty performance emerged. Moreover, executive function scores were comparable between groups at baseline. As a result, subsequent analyses were collapsed across groups. The second aim of the study was to examine whether executive function (i.e., shifting, inhibition, and updating) predicted soccer penalty performance through the mediator of visual attention (i.e., quiet eye duration and location, search rate, and fixations to key locations), while controlling for important covariates (i.e., physical activity and expertise). Results showed numerous significant mediations highlighting the important interaction between executive function and visual attention and the subsequent impact upon sport performance.

The results of the manipulation check provided mixed findings. A significant effect of pressure instructions on situational stress across all participants, independent of group (i.e., low- and high-pressure) was found. However, despite different pressure instructions (following Brimmell et al., 2019) the high-pressure group did not report greater situational stress compared to their low-pressure counterparts. It is possible that informing both groups about the presence of a goalkeeper, albeit only the high-pressure group were explicitly informed that the goalkeeper would try to save their soccer penalty, was enough to evoke situational stress. In terms of ACT-S, the mere presence and mention of a threat to performance (i.e., a goalkeeper) could have been enough to bring about changes in situational stress, yet the additional instructions in the high-pressure group were unable to evoke any additional pressure/stress in the soccer penalty task.

In addition, ACT-S makes some specific predictions about potential determinants of anxiety that may have impacted these data and that were beyond the scope of the current study. Namely, that cognitive biases in performance monitoring (i.e., a bias toward physical and mental errors), perception of failure (i.e., the cost and likelihood of failure), and motivation (i.e., highly motivated individuals are more likely to maintain goal-directed attention, potentially through increased effort) could have affected the situational stress response (Eysenck & Wilson, 2016). As such, it may be that more distinct instructions were needed or additional measurement of these determinants (e.g., motivation) were warranted. Wood and Wilson (2010a) used different instructional sets to successfully create different pressure conditions by informing one group that the task aims were to check the reliability of an eye-tracker while another group received instructions similar to the high-pressure group in the present study (e.g., prizes and leader boards). We concluded that both our pressure instructions were sufficient to increase situational stress, yet our data suggested that self-reported situational stress was not significantly different between the conditions, nor were any of our other test variables. As such, we suggest that our data represented performance within a general pressurised situation only, and not performance across two pressure conditions (i.e., high- and low-pressure).

The present study supports limited research that has proposed a link between inhibition, visual attention, and sport performance (e.g., Ducrocq et al., 2016). Ducrocq et al. (2016) found that, following inhibition training, participants first fixation to a task-relevant target was significantly later (indicating superior inhibition and visual attention) and performance on a tennis task was significantly improved. Here, quiet eye duration significantly mediated the inhibition-soccer penalty performance relationship. This may expand upon previous work (i.e., Ducrocq et al., 2016) in that, not only is superior inhibition (an ability to withhold prepotent responses) associated with delayed first fixations to task-relevant targets, but also associated with a lengthened quiet eye duration. It may be possible that an ability to 'ignore' distracting stimuli increases the time for processing task-relevant information (i.e., the quiet eye period; Vickers, 2007), which in turn allows for more distally placed kicks and superior soccer penalty performance.

One assumption of ACT-S is that anxious or stress-prone individuals are hypervigilant to stimuli that can 'threaten' goal attainment (Eysenck & Wilson, 2016). While research examining visual attention and sport performance has included both threatening (e.g., a goalkeeper) and goal-directed (i.e., the goal) stimuli (e.g., Binsch et al., 2010), previous work on executive function, visual attention, and sport performance has often only included stimuli that is task-relevant (i.e., a tennis target; Ducrocq et al., 2016) and not stimuli that may ‘threaten’ task success. The inclusion of specific goal-directed (i.e., the goal) and threatening (i.e., the goalkeeper) stimuli in the present study allowed for a direct test of this ACT-S assumption and thus, greater ecological validity. Mediation revealed that greater inhibition led to more fixations to goal-directed stimuli (i.e., the goal), and improved subsequent soccer penalty performance. This may support ACT-S in that greater inhibition appears to lead to superior goal-directed attention. Search rate also mediated the inhibition-soccer penalty performance relationship, with the present work being the first to examine this relationship. Research has suggested search rate can influence performance (e.g., Vine et al., 2015), however the cognitive underpinnings have not yet been considered. Search rate may derive from inhibition, with poor inhibition (i.e., failure to resist distraction) causing high search rate due to an inability to maintain gaze upon goal-related stimuli (e.g., the goal), and instead gaze ‘jumps’ between visual locations resulting in inefficient information pick-up and poorer subsequent performance (Eysenck & Wilson, 2016).

The updating-soccer penalty performance relationship was significantly mediated by quiet eye duration which suggested that an ability to maintain goal-directed attention (via superior updating) may allow for longer quiet eye durations and better soccer penalty performance under stressful conditions. This supports limited research reporting a relationship between updating, quiet eye duration, and sport performance (e.g., Ducrocq et al., 2017; Wood et al., 2016). Specifically, that poor updating ability can lead to a reduction in goal-directed attention when faced with possible interfering stimuli (Wood et al., 2016). Quiet eye location also significantly mediated the updating-soccer penalty performance relationship further supporting a link between the cognitive process of updating and the quiet eye phenomenon. This result suggests that an enhanced ability to update information within working-memory not only allows for one to extend the period of critical information processing, but also for more goal-directed final fixation locations (i.e., more distal quiet eye locations).

We also expand upon previous research by showing that, as well as affecting the quiet eye duration and location, updating may affect the number of fixations to goal-directed stimuli. Greater updating may result in more fixations to task-relevant areas of the visual field (i.e., the goal) indicating more optimal goal-directed attention. This result showed that not only does superior updating facilitate more goal-directed final fixations (i.e., distal quiet eye locations) but may also allow for an increased number of fixations to goal-directed stimuli (i.e., the goal) which positively impacts subsequent soccer penalty performance. Moreover, it is possible that the control element of working-memory, tapped by updating, facilitates interaction between attentional and cognitive processes which in turn improve performance (i.e., updating acts as control mechanism between processing facilities; Vaughan & Laborde, 2020).

The number of fixations to the goalkeeper did not mediate any executive function-soccer penalty performance relationships. This is somewhat surprising as the goalkeeper may have represented threatening stimuli within the current task and has been previously shown to operate as a distractor during soccer penalty kicks (Wood & Wilson, 2010a). However, ACT-S states that optimal performance stems from a balance between the two attentional systems (Eysenck & Wilson, 2016). To achieve balance, some attention must be paid to potentially task-threatening stimuli (i.e., the goalkeeper), but superior attentional control comes when individuals are also able to direct more attention to goal-directed stimuli (i.e., the goal). Wood and Wilson (2010a) note that gaze is typically directed toward the ball during a run-up, while hypothetical, it could be that participants with poorer executive function may have directed attention toward the ball during the pre-run-up as well (to ensure accurate contact;

Wood & Wilson, 2010b) rather than directing gaze to goal-directed areas likely to lead to success (i.e., the goal) or the stimuli that may ‘threaten’ their success (i.e., the goalkeeper).

Shifting did not appear in any significant mediation models and the use of the Flanker task offers a potential explanation for this. This task was selected as it requires visuospatial shifts away from distracting ‘flanker’ stimuli (Posner, 2016), potentially increasing the relevance to objective visual attention measures, but this did not emerge. Miyake et al. (2000), and indeed ACT-S, do not explicitly refer to visuospatial shifting, but rather an ability to shift between tasks, operations, or mental sets. Therefore, a task involving switching between rule sets (e.g., the category switch task; Friedman et al., 2008) may be more theoretically suitable. Moreover, Miyake et al. (2000) suggest that, although distinct, inhibition, shifting, and updating do correlate with one another. While updating and inhibition correlated in the present study shifting did not correlate with either of these executive functions, which suggested that the task may not tap an appropriate theoretical shifting ability (unlike the category switch task that requires alternating between two rulesets based on cue word; Friedman et al., 2008). Interestingly, shifting did correlate with the number of fixations to the goalkeeper, which suggested that, while perhaps not a theoretically suitable task, visual shifting, and the ability to divert attention from threatening stimuli (e.g., the goalkeeper) may relate.

The present study offered important implications for ACT-S (Eysenck & Wilson, 2016). Limited work has shown that after training the executive functions proposed by ACT-S, visual attention and sport performance are improved in a subsequent task (e.g., Ducrocq et al., 2016; 2017). Here, we strengthen this theoretical association by showing that inhibition and updating have a direct impact upon visual attention (i.e., quiet eye duration, search rate, and fixations to the goal area), which together influence soccer penalty performance. This finding may also be of interest to coaches and practitioners. More specifically, being the first study to demonstrate a direct relationship between the inhibition, updating and visual attention, we offer preliminary support for the potential advantages of training these separate components. Further work is needed to confirm such benefits.

Limitations and Future Directions

While novel, the present study was not without limitation. First, many aspects of the study could be enhanced through the use of multiple measures. For example, different cognitive paradigms may require different cognitive abilities. The Stop Signal and Go/No-Go paradigms require different inhibition abilities (i.e., controlled and automatic). Therefore, it may be optimal to administer multiple tests of each executive function (i.e., inhibition, shifting, and updating) to ensure numerous relevant abilities are captured and reliability between tasks. This may be particularly relevant for shifting in the current study and to rule out that effects are task specific. Also, it may be optimal for future work to use multiple measures of situational anxiety (i.e., a more direct assessment of anxiety such as the Mental Readiness Form; Krane, 1994) to better detect differences between conditions.

The present study was unable to create two distinct pressure conditions (i.e., low- and high-pressure) therefore future research may wish to use more distinct instructional sets (Wood & Wilson, 2010a). Also, the between-subjects design may mean that individual differences in interpretation of the situation may unknowingly reduce the effects of the pressure instructions. Future research could use a within-subjects design allowing for comparisons between individual performance at low- and high-pressure levels. Also, a within-subjects design could allow for further understanding of how these executive functions affect performance at varying levels of pressure. Finally, the cross-sectional design limits causality and direction, thus, future research should examine this relationship longitudinally to increase confidence in the observed effects. Specifically, obtaining executive function, visual attention, and sport performance data over multiple timepoints, or across a playing season (as in Hagyard et al., 2021), would enable researchers to examine whether changes in scores impact performance and better ascertain direction of effects.

Conclusion

The present study is the first to offer an explanatory pathway between executive function and soccer penalty performance under pressure via visual attention. Greater inhibition and updating ability allowed for longer quiet eye durations, more distal quiet eye locations, more fixations toward the goal (i.e., goal-directed stimuli), and, for inhibition only, lower search rate which in turn led to improved soccer penalty kicks. In sum, better cognitive functioning and visual attention can lead to superior soccer penalty performance.

Footnote:

[1]Despite the aiming phase being reported as more important for aiming processes and more susceptible to anxiety, we also assessed whether visual attention during the execution phase was related to soccer penalty performance and/or differed between the groups in our Supplementary Material.

References

Baumeister, R. F. (1984). Choking under pressure: self-consciousness and paradoxical effects of incentives on skillful performance. *Journal of Personality and Social Psychology*, *46*(3), 610.

Baumeister, R. F., & Showers, C. J. (1986). A review of paradoxical performance effects: Choking under pressure in sports and mental tests. *European Journal of Social Psychology*, *16*(4), 361-383.

Binsch, O., Oudejans, R. R., Bakker, F. C., & Savelsbergh, G. J. (2010). Ironic effects and final target fixation in a penalty shooting task. *Human Movement Science*, *29*(2), 277-288.

Booth, M. (2000). Assessment of physical activity: an international perspective. *Research Quarterly for Exercise and Sport*, *71*, 114-120.

Brimmell, J., Parker, J., Wilson, M. R., Vine, S. J., & Moore, L. J. (2019). Challenge and threat states, performance, and attentional control during a pressurized soccer penalty task. *Sport, Exercise, and Performance Psychology*, *8*(1), 63-79.

Brugnera, A., Zarbo, C., Adorni, R., Tasca, G. A., Rabboni, M., Bondi, E., Compare, A., & Sakatani, K. (2017). Cortical and cardiovascular responses to acute stressors and their relations with psychological distress. *International Journal of Psychophysiology*, *114*, 38-46.

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

Diamond, A., & Ling, D. S. (2016). Conclusions about interventions, programs, and approaches for improving executive functions that appear justified and those that, despite much hype, do not. *Developmental Cognitive Neuroscience*, *18*, 34-48.

Ducrocq, E., Wilson, M., Vine, S., & Derakshan, N. (2016). Training attentional control improves cognitive and motor task performance. *Journal of Sport and Exercise Psychology*, *38*(5), 521-533.

Ducrocq, E., Wilson, M., Smith, T. J., & Derakshan, N. (2017). Adaptive working memory training reduces the negative impact of anxiety on competitive motor performance. *Journal of Sport and Exercise Psychology*, *39*(6), 412-422.

Edwards, E. J., Edwards, M. S., & Lyvers, M. (2015). Cognitive trait anxiety, situational stress, and mental effort predict shifting efficiency: Implications for attentional control theory. *Emotion*, *15*(3), 350.

Erickson, K. I., Hillman, C. H., & Kramer, A. F. (2015). Physical activity, brain, and cognition. *Current Opinion in Behavioral Sciences*, *4*, 27-32.

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

Eysenck, M. W., & Wilson, M. R. (2016). Sporting performance, pressure, and cognition: Introducing attentional control theory: Sport. In D. Groome, & M. Eysenck (Eds.), *An introduction to applied cognitive psychology* (2nd ed., pp. 329-350). London: Routledge.

Field, A. (2013). *Discovering statistics using IBM SPSS statistics* (4th Ed). Sage.

Friedman, N. P., & Miyake, A. (2004). The relations among inhibition and interference control functions: a latent-variable analysis. *Journal of Experimental Psychology: General*, *133*(1), 101.

Friedman, N. P., Miyake, A., Young, S. E., DeFries, J. C., Corley, R. P., & Hewitt, J. K. (2008). Individual differences in executive functions are almost entirely genetic in origin. *Journal of Experimental Psychology: General*, *137*(2), 201.

Furley, P. A., & Memmert, D. (2012). Working memory capacity as controlled attention in tactical decision making. *Journal of Sport and Exercise Psychology*, *34*(3), 322-344.

Furley, P., & Wood, G. (2016). Working memory, attentional control, and expertise in sports: A review of current literature and directions for future research. *Journal of Applied Research in Memory and Cognition*, *5*(4), 415-425.

Hagstromer, M., Oja, P., & Sjostrom, M. (2006). The International Physical Activity Questionnaire (IPAQ): a study of concurrent and construct validity. *Public Health Nutrition*, *9*(6), 755-762.

Hagyard, J. D., Brimmell, J., Edwards, E. E., & Vaughan, R. S. (2021). Inhibitory control across athletic expertise and its relationship with sport performance. *Journal of Sport and Exercise Psychology*, *43(1)*, 14-27.

Harris, D. J., Vine, S. J., Eysenck, M. W., & Wilson, M. R. (2019). To err again is human: exploring a bidirectional relationship between pressure and performance failure feedback. *Anxiety, Stress, & Coping*, *32*(6), 670-678.

Hayes, A. F. (2018). *Introduction to mediation, moderation, and conditional process analysis: A regression-based approach*. London: Guilford.

Hedge, C., Powell, G., & Sumner, P. (2018). The reliability paradox: Why robust cognitive tasks do not produce reliable individual differences. *Behavior Research Methods*, *50*(3), 1166-1186.

Hughes, M. M., Linck, J. A., Bowles, A. R., Koeth, J. T., & Bunting, M. F. (2014). Alternatives to switch-cost scoring in the task-switching paradigm: Their reliability and increased validity. *Behavior Research Methods*, *46*(3), 702-721.

Huijgen, B. C., Leemhuis, S., Kok, N. M., Verburgh, L., Oosterlaan, J., Elferink-Gemser, M. T., & Visscher, C. (2015). Cognitive functions in elite and sub-elite youth soccer players aged 13 to 17 years. *PLoS One*, *10*(12), e0144580.

Jaeggi, S. M., Studer-Luethi, B., Buschkuehl, M., Su, Y. F., Jonides, J., & Perrig, W. J. (2010). The relationship between n-back performance and matrix reasoning—implications for training and transfer. *Intelligence*, *38*(6), 625-635.

Kenny, D. A. (2017, February). MedPower: An interactive tool for the estimation of power in tests of mediation [Computer software]. Available from https://davidakenny.shinyapps.io/MedPower/

Klostermann, A., & Moeinirad, S. (2020). Fewer fixations of longer duration? Expert gaze behavior revisited. *German Journal of Exercise and Sport Research*, 1-16.

Kredel, R., Vater, C., Klostermann, A., & Hossner, E. J. (2017). Eye-tracking technology and the dynamics of natural gaze behavior in sports: A systematic review of 40 years of research. *Frontiers in Psychology*, *8*, 1845.

Krenn, B., Finkenzeller, T., Würth, S., & Amesberger, G. (2018). Sport type determines differences in executive functions in elite athletes. *Psychology of Sport and Exercise*, *38*, 72-79.

Krane, V. (1994). The mental readiness form as a measure of competitive state anxiety. *The Sport Psychologist*, *8*(2), 189-202.

Kuhn, W. (1988). Penalty-kick strategies for shooters and goalkeepers. *Science and Football*, 489-492.

Langenecker, S. A., Zubieta, J. K., Young, E. A., Akil, H., & Nielson, K. A. (2007). A task to manipulate attentional load, set-shifting, and inhibitory control: Convergent validity and test–retest reliability of the Parametric Go/No-Go Test. *Journal of Clinical and Experimental Neuropsychology*, *29*(8), 842-853.

Lebeau, J. C., Liu, S., Sáenz-Moncaleano, C., Sanduvete-Chaves, S., Chacón-Moscoso, S., Becker, B. J., & Tenenbaum, G. (2016). Quiet eye and performance in sport: A meta-analysis. *Journal of Sport and Exercise Psychology*, *38*(5), 441-457.

Mann, D. T., Williams, A. M., Ward, P., & Janelle, C. M. (2007). Perceptual-cognitive expertise in sport: A meta-analysis. *Journal of Sport and Exercise Psychology*, *29*(4), 457-478.

Miyake, A., Friedman, N. P., Emerson, M. J., Witzki, A. H., Howerter, A., & Wager, T. D. (2000). The unity and diversity of executive functions and their contributions to complex “frontal lobe” tasks: A latent variable analysis. *Cognitive Psychology*, *41*(1), 49-100.

Moore, L. J., Wilson, M. R., Vine, S. J., Coussens, A. H., & Freeman, P. (2013). Champ or chump?: Challenge and threat states during pressurized competition. *Journal of Sport and Exercise Psychology*, *35*(6), 551-562.

Nibbeling, N., Oudejans, R. R., & Daanen, H. A. (2012). Effects of anxiety, a cognitive secondary task, and expertise on gaze behavior and performance in a far aiming task. *Psychology of Sport and Exercise*, *13*(4), 427-435.

Nigg, C. R., Fuchs, R., Gerber, M., Jekauc, D., Koch, T., Krell-Roesch, J., Lippke, S., Mnich, C., Novak, B., Ju, Q., Sattler, M. C., Schmidt, S. C. E., van Poppel, M., Reimers, A. K., Wagner, P., Woods, C., & Woll, A. (2020). Assessing physical activity through questionnaires – A consensus of best practices and future directions. *Psychology of Sport and Exercise*, 101715.

Otten, M. (2009). Choking vs. clutch performance: A study of sport performance under pressure. *Journal of Sport and Exercise Psychology*, *31*(5), 583-601.

Oudejans, R. R., Kuijpers, W., Kooijman, C. C., & Bakker, F. C. (2011). Thoughts and attention of athletes under pressure: skill-focus or performance worries?. *Anxiety, Stress, & Coping*, *24*(1), 59-73.

Posner, M. I. (2016). Orienting of attention: Then and now. *The Quarterly Journal of Experimental Psychology*, *69*(10), 1864-1875.

Preacher, K. J., & Hayes, A. F. (2008). Asymptotic and resampling strategies for assessing and comparing indirect effects in multiple mediator models. *Behavior Research Methods*, *40*(3), 879-891.

Ree, M. J., French, D., MacLeod, C., & Locke, V. (2008). Distinguishing cognitive and somatic dimensions of state and trait anxiety: Development and validation of the State-Trait Inventory for Cognitive and Somatic Anxiety (STICSA). *Behavioural and Cognitive Psychotherapy*, 36(3), 313.

Ridderinkhof, K. R., van der Molen, M. W., Band, G. P., & Bashore, T. R. (1997). Sources of interference from irrelevant information: A developmental study. *Journal of Experimental Child Psychology*, *65*(3), 315-341.

Shelton, J. T., Elliott, E. M., Hill, B. D., Calamia, M. R., & Gouvier, W. D. (2009). A comparison of laboratory and clinical working memory tests and their prediction of fluid intelligence. *Intelligence*, *37*(3), 283-293.

Swann, C., Moran, A., & Piggott, D. (2015). Defining elite athletes: Issues in the study of expert performance in sport psychology. *Psychology of Sport and Exercise*, *16*, 3-14.

Tabachnick, B.G., & Fidell, L.S. (2007). *Using multivariate statistics*. Boston: Allyn and Bacon.

Timmis, M. A., Piras, A., & van Paridon, K. N. (2018). Keep your eye on the ball: The impact of an anticipatory fixation during successful and unsuccessful soccer penalty kicks. *Frontiers in Psychology*, *9*, 2058.

van der Kamp, J. (2006). A field simulation study of the effectiveness of penalty kick strategies in soccer: Late alterations of kick direction increase errors and reduce accuracy. *Journal of Sports Sciences*, *24*(05), 467-477.

van der Kamp, J., & Masters, R. S. (2008). The human Müller-Lyer illusion in goalkeeping. *Perception*, *37*(6), 951-954.

Vaughan, R. S., & Edwards, E. J. (2020). Executive function and personality: The moderating role of athletic expertise. *Personality and Individual Differences, 161*, 109973.

Vaughan, R. S., & Laborde, S. (2020). Attention, working-memory control, working-memory capacity, and sport performance: The moderating role of athletic expertise. *European Journal of Sport Science*, *12*(2), 1-10.

Verbruggen, F., & Logan, G. D. (2008). Automatic and controlled response inhibition: associative learning in the go/no-go and stop-signal paradigms. *Journal of Experimental Psychology: General*, *137*(4), 649.

Verburgh, L., Scherder, E. J. A., van Lange, P. A., Oosterlaan, J. (2014). Executive functioning in highly talented soccer players. *PLoS One*, *9*(3), e91254.

Vestberg, T., Reinebo, G., Maurex, L., Ingvar, M., Petrovic, P., & Ardigò, L. P. (2017). Core executive functions are associated with success in young elite soccer players. *PLoS One*, *12*(2), e0170845.

Vickers, J. N. (2007). *Perception, cognition, and decision training: The quiet eye in action*. Champaign, IL: Human Kinetics.

Vine, S. J., Uiga, L., Lavric, A., Moore, L. J., Tsaneva-Atanasova, K., & Wilson, M. R. (2015). Individual reactions to stress predict performance during a critical aviation incident. *Anxiety, Stress, & Coping*, *28*(4), 467-477.

Votruba, K. L., & Langenecker, S. A. (2013). Factor structure, construct validity, and age- and education-based normative data for the Parametric Go/No-Go Test. *Journal of Clinical and Experimental Neuropsychology*, *35*(2), 132-146.

Wendt, M., Klein, S., & Strobach, T. (2017). More than attentional tuning–investigating the mechanisms underlying practice gains and preparation in task switching. *Frontiers in Psychology*, *8*, 682.

Wilson, M. R., Vine, S. J., & Wood, G. (2009). The influence of anxiety on visual attentional control in basketball free throw shooting. *Journal of Sport and Exercise Psychology*, *31*(2), 152-168.

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.

Wood, G., & Wilson, M. R. (2010a). A moving goalkeeper distracts penalty takers and impairs shooting accuracy. *Journal of Sports Sciences*, *28*(9), 937-946.

Wood, G., & Wilson, M. R. (2010b). Gaze behaviour and shooting strategies in football penalty kicks: Implications of a" keeper-dependent" approach. *International Journal of Sport Psychology*, *41*(3), 293.

Wood, G., & Wilson, M. R. (2011). Quiet-eye training for soccer penalty kicks. *Cognitive Processing*, *12*(3), 257-266.

Wood, G., Vine, S. J., & Wilson, M. R. (2016). Working memory capacity, controlled attention and aiming performance under pressure. *Psychological Research*, *80*(4), 510-517.

Wood, G., Vine, S. J., Parr, J., & Wilson, M. R. (2017). Aiming to deceive: Examining the role of the quiet eye during deceptive aiming actions. *Journal of Sport and Exercise Psychology*, *39*(5), 327-338.

Table 1. Means, Standard Deviations, and Zero-Order Correlations for all variables.

Variable	Total (N = 95) M(SD)	High-Pressure (N = 48)	Low-Pressure (N = 47)	Zero-Order Correlations (N = 95)												
		M(SD)	M(SD)	1	2	3	4	5	6	7	8	9	10	11	12	13
1. SRQ baseline	12.91(6.35)	12.92(6.21)	12.89(6.55)	1	.64**	-.47**	-.50**	-.05	-.18	-.01	-.19	-.09	.16	-.06	.01	-.16
2. SRQ post-instruction	15.54(7.44)	16.52(7.76)	14.53(7.03)		1	-.40**	-.35**	-.08	-.25*	.01	-.22*	-.04	.23*	-.08	.06	-.20*
3. IPAQ-SF	5803.04(3813.01)	5919.77(3775.58)	5683.83(3888.01)			1	.53**	.20	.07	.04	.30**	.05	-.26*	.01	.02	.21*
4. Expertise	2.78(3.28)	2.51(3.12)	3.07(3.45)				1	-.03	.15	.16	.25*	.17	-.31**	.04	-.04	.33**
5. Shifting	7.37(5.46)	7.83(5.88)	6.90(5.04)					1	.02	-.10	.14	-.16	-.04	-.04	-.21*	.11
6. Inhibition	15.45(4.79)	15.35(5.08)	15.55(4.52)						1	.25**	.27**	.19	-.29**	.28**	-.07	.22*
7. Updating	.18(1.58)	.12(1.54)	.23(1.65)							1	.20	.31**	-.19	.27**	.03	.16
8. Quiet Eye Duration	184.90(59.04)	189.96(68.52)	179.85(47.95)								1	.31**	-.67**	.33**	.01	.49**
9. Quiet Eye Location	50.59(46.96)	51.25(49.64)	49.89(45.21)									1	-.23*	.55**	-.21	.47**
10. Search Rate	5.73(1.26)	5.72(1.28)	5.74(1.27)										1	-.28**	-.29**	-.48**
11. Total Number of Fixations to the Goal	1.70(1.76)	1.65(1.76)	1.76(1.79)											1	-.05	.28**
12. Total Number of Fixations to the GK	1.68(1.50)	1.60(1.57)	1.76(1.45)												1	-.23*
13. Performance	76.53(60.12)	69.79(63.96)	83.40(55.78)													1

Note. SRQ = Stress Rating Questionnaire; IPAQ-SF = International Physical Activity Questionnaire Short Form; GK = Goalkeeper. * $p < .05$ ** $p < .01$.

Table 2. Summary of mediation analyses for quiet eye duration.

Effect	Coefficient	SE	Bootstrapping 95% CI	
X = Shifting	Y = Performance		Lower	Upper
Total effect (c)	1.39	1.19	-0.97	3.76
Direct effect (c′)	.55	1.05	-1.53	2.63
Indirect effects				
Total indirect effects	.85	.69	-0.36	2.39
a (X – M)	1.57	1.11	-0.63	3.78
b (M- Y)	.54	.10	0.34	0.74
X = Inhibition	Y = Performance		Lower	Upper
Total effect (c)	2.42	1.25	-0.07	4.90
Direct effect (c′)	1.09	1.12	-1.14	3.33
Indirect effects				
Total indirect effects	1.32	.63	0.10	2.63
a (X – M)	2.49	1.16	0.19	4.80
b (M- Y)	.53	.10	0.33	0.73
X = Updating	Y = Performance		Lower	Upper
Total effect (c)	4.05	3.87	-3.65	11.75
Direct effect (c’)	.47	3.42	-6.34	7.27
Indirect effects				
Total indirect effects	3.58	1.73	0.66	7.39
a (X – M)	6.51	3.56	-0.57	13.60
b (M- Y)	.55	.10	0.35	0.75

Note. X = Predictor; M = Mediator; Y = Outcome; CI = Confidence Interval.

Table 3. Summary of mediation analyses for quiet eye location.

Effect	Coefficient	SE	Bootstrapping 95% CI	
X = Shifting	Y = Performance		Lower	Upper
Total effect (c)	1.05	1.14	-1.22	3.33
Direct effect (c′)	1.79	1.03	-.26	3.84
Indirect effects				
Total indirect effects	-.74	.52	-1.76	.30
a (X – M)	-1.30	.93	-3.15	.55
b (M- Y)	.57	.12	.34	.80
X = Inhibition	Y = Performance		Lower	Upper
Total effect (c)	2.28	1.24	-.18	4.73
Direct effect (c′)	1.49	1.14	-.82	3.72
Indirect effects				
Total indirect effects	.83	.52	-.16	1.90
a (X – M)	1.60	1.01	-.42	3.61
b (M- Y)	.52	.11	.29	.75
X = Updating	Y = Performance		Lower	Upper
Total effect (c)	4.56	3.79	-2.97	12.09
Direct effect (c’)	-.08	3.60	-7.23	7.07
Indirect effects				
Total indirect effects	4.64	1.77	1.63	8.59
a (X – M)	8.54	2.98	2.62	14.46
b (M- Y)	.54	.12	.30	.79

Note. X = Predictor; M = Mediator; Y = Outcome; CI = Confidence Interval.

Table 4. Summary of mediation analyses for search rate.

Effect	Coefficient	SE	Bootstrapping 95% CI	
X = Shifting	Y = Performance		Lower	Upper
Total effect (c)	1.17	1.13	-1.07	3.41
Direct effect (c′)	1.04	1.02	-0.99	3.07
Indirect effects				
Total indirect effects	.13	.52	-0.84	1.21
a (X – M)	-.01	.02	-0.05	0.04
b (M- Y)	-20.53	4.56	-29.59	-11.48
X = Inhibition	Y = Performance		Lower	Upper
Total effect (c)	2.40	1.24	-0.07	4.87
Direct effect (c′)	1.13	1.18	-1.21	3.46
Indirect effects				
Total indirect effects	1.27	.58	0.26	2.54
a (X – M)	-.06	.03	-0.12	-0.01
b (M- Y)	-19.88	4.65	-29.12	-10.65
X = Updating	Y = Performance		Lower	Upper
Total effect (c)	4.09	3.78	-3.42	11.61
Direct effect (c’)	1.58	3.48	-5.33	8.49
Indirect effects				
Total indirect effects	2.51	1.73	-0.58	6.26
a (X – M)	-.12	.08	-0.28	0.04
b (M- Y)	-20.67	4.57	-29.76	-11.59

Note. X = Predictor; M = Mediator; Y = Outcome; CI = Confidence Interval.

Table 5. Summary of mediation analyses for the number of fixations to the goal area.

Effect	Coefficient	SE	Bootstrapping 95% CI	
X = Shifting	Y = Performance		Lower	Upper
Total effect (c)	1.16	1.13	-1.09	3.41
Direct effect (c′)	1.28	1.10	-0.90	3.47
Indirect effects				
Total indirect effects	-.12	.33	-0.79	0.56
a (X – M)	-.01	.04	-0.08	0.06
b (M- Y)	8.66	3.32	2.05	15.26
X = Inhibition	Y = Performance		Lower	Upper
Total effect (c)	2.51	1.26	0.01	5.01
Direct effect (c′)	1.68	1.29	-0.88	4.25
Indirect effects				
Total indirect effects	.82	.44	0.03	1.73
a (X – M)	.11	.04	0.04	0.19
b (M- Y)	7.44	3.45	0.59	14.29
X = Updating	Y = Performance		Lower	Upper
Total effect (c)	4.32	3.83	-3.29	11.93
Direct effect (c’)	1.87	3.86	-5.80	9.55
Indirect effects				
Total indirect effects	2.45	1.38	0.32	5.69
a (X – M)	.29	.11	0.07	0.52
b (M- Y)	8.33	3.44	1.49	15.17

Note. X = Predictor; M = Mediator; Y = Outcome; CI = Confidence Interval.

Table 6. Summary of mediation analyses for the number of fixations to the goalkeeper.

Effect	Coefficient	SE	Bootstrapping 95% CI	
X = Shifting	Y = Performance		Lower	Upper
Total effect (c)	1.02	1.14	-1.24	3.28
Direct effect (c′)	.52	1.15	-1.76	2.79
Indirect effects				
Total indirect effects	.50	.32	-0.03	1.22
a (X – M)	-.06	.03	-0.12	-0.01
b (M- Y)	-8.10	4.07	-16.19	-0.01
X = Inhibition	Y = Performance		Lower	Upper
Total effect (c)	2.48	1.25	-0.02	4.97
Direct effect (c′)	2.26	1.24	-0.20	4.73
Indirect effects				
Total indirect effects	.22	30	-0.30	0.92
a (X – M)	-.03	.03	-0.09	0.04
b (M- Y)	-7.64	3.92	-15.43	0.15
X = Updating	Y = Performance		Lower	Upper
Total effect (c)	4.72	3.82	-2.86	12.31
Direct effect (c’)	4.95	3.74	-2.49	12.39
Indirect effects				
Total indirect effects	-.23	.94	-1.94	1.94
a (X – M)	.03	.10	-0.17	0.23
b (M- Y)	-8.43	3.94	-16.26	-0.60

Note. X = Predictor; M = Mediator; Y = Outcome; CI = Confidence Interval.

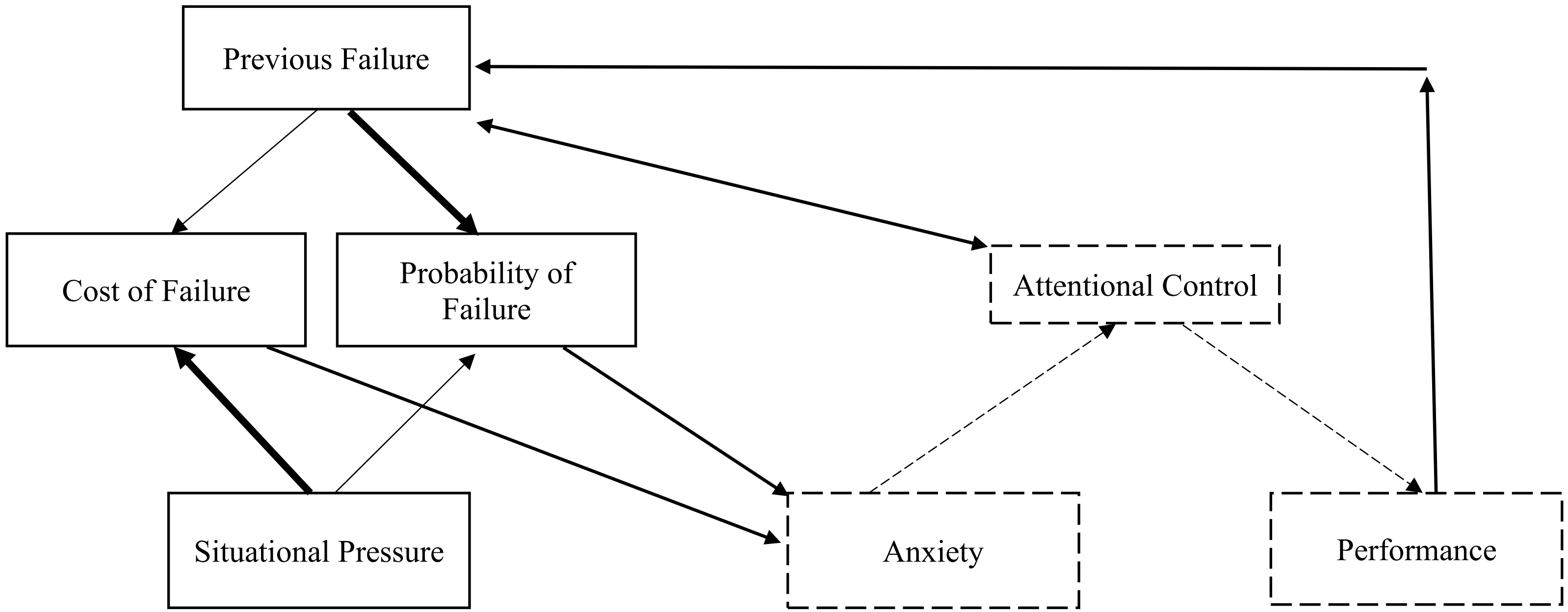

Figure 1. Adapted from Harris et al. (2019) this schematic diagram shows the theoretical assumptions of Attentional Control Theory (Eysenck et al., 2007; dashed lines) and Attentional Control Theory-Sport (Eysenck & Wilson, 2016; solid lines). The model shows that individual responses are influenced by perceived costs of failure (primarily influenced by interpretations of situational pressure; indicated by the bold line) and the probability of failure (primarily influenced by interpretation of preceding failures; indicated by the bold line).