Challenge and threat states, performance, and attentional control during a pressurized soccer penalty task

Jack Brimmell, John Parker, Mark Wilson, Samuel Vine, & Lee Moore.

2018.

Abstract

The integrative framework of stress, attention, and visuomotor performance was developed to explain the benefits of responding to competitive pressure with a challenge rather than a threat state. However, to date, the specific predictions of this framework have not been tested. Forty-two participants completed two trials of a pressurized soccer penalty task. Before the first trial, challenge and threat states were assessed via demand and resource evaluations and cardiovascular reactivity. Performance and gaze behavior were then recorded during the first trial. Before the second trial, challenge and threat states were measured again through demand and resource evaluations and cardiovascular reactivity. A challenge state, indexed by evaluations that coping resources matched or exceeded task demands, and higher cardiac output and/or lower total peripheral resistance reactivity, was associated with superior performance, with the cardiovascular response predicting performance more strongly. Furthermore, a challenge-like cardiovascular response was related to longer quiet eye durations and lower search rates, marginally more fixations towards the goal and ball, and more time spent fixating the goal and other locations (e.g., ground). However, none of the attentional variables mediated the relationship between challenge and threat states and performance, suggesting more research is needed to elucidate underlying mechanisms. Finally, although performing well on trial one was marginally associated with evaluating the second trial as a challenge, no support was found for the other feedback loops. The findings offer partial support for the integrative framework and imply that practitioners should foster a challenge state to optimize performance under pressure.

Keywords: Psychophysiology; stress; appraisal; demand and resource evaluations; cardiovascular reactivity

Introduction

When faced with pressure, athletes are expected to thrive. However, stress can have divergent effects on the performance of athletes, with some rising to the occasion and excelling, and others struggling to cope and failing. Athletes' psychophysiological responses to stress (e.g., challenge and threat states) are thought to determine such performance variability under pressure (Jones, Meijen, McCarthy, & Sheffield, 2009). In order to shed more light on the relationship between psychophysiological reactions to stress and sports performance, and delineate possible underlying mechanisms, this study offered a novel investigation of the assumptions of the integrative framework of stress, attention, and visuomotor performance (Figure 1 - Vine, Moore, & Wilson, 2016).

>>>>>>>>>>Figure 1 Near Here<<<<<<<<<<

The integrative framework incorporates the key predictions of the biopsychosocial model (BPSM) of challenge and threat states (Blascovich, 2008). According to the BPSM, the psychophysiological states of challenge and threat only occur when athletes are actively engaged in an arousing situation (evidenced by increases in heart rate; Seery, 2011). Once engaged, athletes evaluate the demands of the situation and their ability to cope (Blascovich, 2008). Athletes who perceive that they possess sufficient resources to cope with the demands of the situation, evaluates the situation as a challenge. In contrast, athletes who judge that they lack the necessary coping resources, evaluate the situation as a threat (Seery, 2013). These demand and resource evaluations are thought to be relatively automatic (i.e., subconscious) and dynamic, as such, while athletes might initially appraise a situation as a challenge, this evaluation could quickly fluctuate in the light of new information (e.g., past performance; Blascovich, 2008). Importantly, challenge and threat are not considered dichotomous states but anchors of a single bipolar continuum, meaning that relative differences are often examined (i.e., greater versus lesser challenge or threat; Seery, 2013).

Distinct neuroendocrine and cardiovascular patterns are predicted to result from these demand and resource evaluations (Blascovich, Vanman, Mendes, & Dickerson, 2011). When athletes evaluate a stressful situation as a challenge, this triggers elevated sympathetic-adrenomedullary activation and the release of catecholamines such as epinephrine and norepinephrine. Consequently, cardiac activity increases (evidenced by elevations in cardiac output), blood vessels dilate (indexed by reductions in total peripheral resistance), and more oxygenated blood is transported to the brain and muscles (Seery, 2011). Conversely, when athletes evaluate a stressful situation as a threat, this evokes pituitary-adrenocortical activation and the release of cortisol, which attenuates sympathetic-adrenomedullary activation. Subsequently, cardiac activity reduces (evidenced by little change or small decreases in cardiac output), dilation of the blood vessels is inhibited (indexed by little change or small increases in total peripheral resistance), and less blood flows to the brain and muscles (Seery, 2011). Thus, compared to a threat state, a challenge state is marked by a cardiovascular response consisting of relatively higher cardiac output and/or lower total peripheral resistance (Seery, 2011). These cardiovascular indices have been extensively validated (Blascovich et al., 2011). For example, Tomaka, Blascovich, Kibler and Ernst (1997) found that participants who received ‘challenge’ instructions evaluated a mental arithmetic task as more of a challenge (i.e., coping resources exceed task demands), and displayed more of a challenge-like cardiovascular response (i.e., greater cardiac output and lower total peripheral resistance), compared to those who received ‘threat’ instructions.

According to the BPSM, a challenge state leads to better performance than a threat state (Blascovich, 2008). Research has supported this proposition in various sporting tasks (Moore, Vine, Wilson, & Freeman, 2012; Turner, Jones, Sheffield, & Cross, 2012; Turner, Jones, Sheffield, Slater, Barker, & Bell, 2013). For example, in a seminal study, Blascovich, Seery, Mugridge, Norris and Weisbuch (2004) found that softball and baseball players who responded to a sport-specific speech with a cardiovascular response more reflective of a challenge state, performed better (i.e., creating more runs) during the subsequent season, than players who reacted with a cardiovascular response more akin to a threat state. More recently, Moore, Wilson, Vine, Coussens and Freeman (2013) found that golfers who evaluated a golf competition as a challenge, outperformed (i.e., shot lower scores) golfers who evaluated the competition as a threat. Furthermore, in a follow-up experimental study, Moore et al. (2013) found that experienced golfers who were manipulated into a challenge state performed better on a pressurized golf putting task (i.e., holing more putts and leaving the ball closer to the hole on average), than golfers who were manipulated into a threat state.

Although the aforementioned predictions of the BPSM are retained within the integrative framework of stress, attention, and visuomotor performance (Vine et al., 2016), the framework also explains the mechanisms that underpin the relationship between challenge and threat states and sports performance. Indeed, consistent with the attentional mechanisms speculated previously (e.g., Blascovich et al., 2004; Jones et al., 2009), the integrative framework proposes that challenge and threat states might influence performance via their effects on two systems influential in the control of attention, the goal-directed (top-down) and stimulus-driven (bottom-up) attentional systems (Corbetta & Shulman, 2002). Specifically, when athletes experience a challenge state, the goal-directed and stimulus-driven systems are balanced, allowing athletes to effectively control their attention, focus on the most salient task-relevant cues, and process the optimal visual information needed to successfully perform the task (Vine et al., 2016). In contrast, when athletes are in a threat state, the stimulus-driven system dominates the goal-directed system, causing athletes to become distracted by less relevant (and potentially threatening) stimuli, preventing athletes from processing the most relevant visual information needed to accurately perform the task (Vine et al., 2016).

To support these predictions, Vine et al. (2016) drew upon existing research demonstrating that challenge and threat states have divergent effects on attentional control (Moore et al., 2012; Vine, Freeman, Moore, Chandra-Ramanan, & Wilson, 2013). For example, Moore et al. (2013) found that compared to golfers who were manipulated into a challenge state, golfers who were manipulated into a threat state before a pressurized golf putting task spent less time looking at the ball before initiating the putting action (i.e., shorter quiet eye durations; Vickers, 2016), indicating inferior goal-directed attention (Lebeau et al., 2016). Moreover, Vine, Uiga, Lavric, Moore and Wilson (2015) found that pilots who evaluated a stressful task (i.e., engine failure on take-off) as a threat displayed a higher search rate (i.e., more fixations of a shorter duration), indicating increased stimulus-driven attention. Despite this research, no studies have examined the propositions of the integrative framework since its conception. In particular, little work has examined the prediction that athletes might be hyper vigilant to negative (or threatening) stimuli during a threat state (Vine et al., 2016). This lack of research is surprising given the results of Frings, Rycroft, Allen and Fenn (2014), who found that participants who were manipulated into a threat state fixated more on an array associated with losing points (i.e., negative stimuli) than participants who were manipulated into a challenge state. Thus, more research is required to test this, and the other core predictions, of the integrative framework.

Of particular interest are the three feedback loops proposed by the integrative framework, which have received scant attention to date (Vine et al., 2016). First, it is suggested that the cardiovascular response accompanying a threat state will further increase the likelihood that athletes will evaluate similar tasks as a threat (i.e., task demands exceed coping resources) in the future. Second, it is proposed that the tendency to focus on task-irrelevant and often threatening stimuli during a threat state will likely prompt athletes to evaluate comparable tasks as a threat in the future. Third, it is argued that athletes who perform poorly during a stressful sporting task are likely to evaluate future tasks as a threat (Vine et al., 2016). Although evidence supporting the first and second feedback loops is scarce, one study has offered evidence relating to the third feedback loop. Indeed, Quigley, Feldman-Barrett and Weinstein (2002) found that performance during a mental arithmetic task (i.e., percentage of correct responses), did not significantly predict demand and resource evaluations before a subsequent mental arithmetic task. Therefore, further research is needed to clarify the relationship between task performance and ensuing demand and resource evaluations.

The present study

To aid theory, intervention development, and our understanding of the impact of psychophysiological responses to stress on sports performance, the present study offered an initial test of the integrative framework of stress, attention, and visuomotor performance (Vine et al., 2016). Specifically, the primary aim of this study was to examine whether challenge and threat states predicted performance and attentional control during a pressurized soccer penalty task. This task was chosen as previous research has shown that anxiety disrupts the attentional control of soccer players, reducing quiet eye durations and causing more (and longer) fixations towards the goalkeeper; the main source of threat towards goal achievement (e.g., Wilson, Wood, & Vine, 2009).

It was hypothesized that participants who evaluated the task as more of a challenge (i.e., coping resources match or exceed task demands), and responded to the task with a cardiovascular response more consistent with a challenge state (i.e., relatively higher cardiac output and/or lower total peripheral resistance reactivity), would perform the task more accurately and display more optimal attentional control (i.e., longer quiet eye durations, lower search rates, more fixations towards, and greater time spent fixating, the goal and ball, and fewer fixations towards, and less time spent fixating, the goalkeeper [threatening stimulus]). Given the predictions of the integrative framework, these measures of attentional control were expected to mediate the relationship between challenge and threat states (i.e., demand and resource evaluations, cardiovascular reactivity) and task performance. Furthermore, the secondary aim of this study was to use a within-subjects design to test the three feedback loops proposed by the integrative framework. It was predicted that participants who exhibited a cardiovascular response more akin to a threat state, spent longer fixating the goalkeeper [threatening cue], and performed less accurately during an initial trial of the pressurized soccer penalty task, would evaluate a second trial of the task as more of a threat (i.e., task demands exceed coping resources), and display a cardiovascular response more reflective of a threat state (i.e., relatively lower cardiac output and/or higher total peripheral resistance reactivity).

Method

Participants

A power analysis using G*Power software (Faul, Erdfelder, Lang, & Butchner, 2007) revealed that, based on the large (β = .64) and medium (β = .37) effect sizes reported by Turner and colleagues (2012; 2013), between 13 and 52 participants were required to achieve a power of .80, given an alpha of .05. Thus, forty-two participants (35 male, 7 female; M_{age} = 23.50 years, *SD* = 6.62) took part in the study. All participants had a minimum of two years' soccer experience ($M_{experience}$ = 12.43 years, *SD* = 6.53). Furthermore, all participants reported being non-smokers, free of illness, injury, or infection, having no known family history of cardiovascular or respiratory disease, having not performed vigorous exercise or ingested alcohol within the last 24 hours, and having not consumed food or caffeine within the last hour. Participants were tested individually. Before testing, institutional ethical approval was obtained, and participants provided written informed consent.

Task Setup

The experimental task was adapted from previous research (e.g., Wilson et al., 2009), and comprised a single kick of a standard indoor soccer ball (20.57 cm diameter) from a penalty spot located 5.0 m from the centre of a regulation-size indoor soccer goal (3.0 m x 1.2 m; JP Lennard, Ltd., Warwickshire, U.K.). The goal was divided into twelve 30 cm vertical sections, which allowed performance to be measured (Wilson et al., 2009). Participants were instructed to begin their run-up from a pre-defined marker located 1.50 m behind the penalty spot. The same goalkeeper was used throughout testing. Given that goalkeeper movement, positioning, and posture have been shown to influence penalty taking accuracy and attentional control (e.g., Van der Kamp & Masters, 2008; Wood, Vine, Parr, & Wilson, 2017), the goalkeeper was instructed to stand still in the centre of the goal with their knees bent and arms spread out to the side for all participants. However, it should be noted that to elevate pressure, participants were informed that the goalkeeper would attempt to save their soccer penalty kick. Participants completed two trials of the pressurized soccer penalty task, but were unaware of the second trial when completing the first trial.

Measures

Demand and resource evaluations. Before each trial, two self-report items from the cognitive appraisal ratio were used to assess evaluations of task demands and personal coping resources (Tomaka, Blascovich, Kelsey, & Leitten, 1993). Demand evaluations were assessed by asking ‘How demanding do you expect the upcoming soccer penalty task to be?’, while resource evaluations were assessed by asking ‘How able are you to cope with the demands of the upcoming soccer penalty task?’ Both items were rated on a 6-point Likert scale anchored between 1 (*not at all*) and 6 (*extremely*). A demand resource evaluation score (DRES) was calculated by subtracting evaluated demands from resources (range: -5 to 5), with a positive score reflective of a challenge state (i.e., coping resources match or exceed task demands), and a negative score representative of a threat state (i.e., task demands exceed coping resources). Although this measure has received little psychometric testing, it has been used in previous research examining challenge and threat states (e.g., Vine et al., 2013), has clear face validity, and has been consistently related to performance across a range of tasks (Hase, O’Brien, Moore, & Freeman, in press), demonstrating predictive validity.

Cardiovascular measures. A non-invasive impedance cardiograph device (Physioflow Enduro, Manatec Biomedical, Paris, France) was used to estimate heart rate (i.e., number of heart beats per minute), cardiac output (i.e., amount of blood ejected from the heart in liters per minute), and total peripheral resistance (i.e., a measure of net constriction versus dilation in the arterial system). The theoretical basis for this device and its validity during rest and exercise has been established previously (e.g., Charloux et al., 2000). The Physioflow measures impedance changes in response to a high-frequency (75.0 kHz) and low-amperage (1.8 mA) electrical current emitted via electrodes. Following preparation of the skin, six spot electrodes (Physioflow PF-50, Manatec Biomedical, Paris, France) were positioned on the thorax of each participant: two on the supraclavicular fossa of the left lateral aspect of the neck, two near the xiphisternum at the mid-point of the thoracic region of the spine, one on the middle part of the sternum, and one on the rib closest to V6. After participants' details were entered (e.g., weight), the Physioflow was calibrated over 30 heart cycles while participants sat still and quietly in an upright position. Two resting systolic and diastolic blood pressure values were obtained (one before and another immediately after the 30 heart cycles) using an automatic blood pressure monitor (Omron M4 Digital BP Meter, Cranlea & Co., Birmingham, UK). The mean blood pressure values were then entered to complete calibration.

Cardiovascular data was estimated continuously during baseline (5 minutes) and post-instruction (1 minute) time periods (Table 1). Participants remained seated, still, and quiet throughout both of these periods. Reactivity, or the difference between the final minute of baseline and the minute after the task instructions, was examined for all cardiovascular variables before the first and second trials of the pressurized soccer penalty task. Heart rate is considered a cardiovascular marker of task engagement, with greater increases in heart rate reflecting greater task engagement (a pre-requisite for challenge and threat states; Seery, 2011). Cardiac output and total peripheral resistance are cardiovascular indices that are proposed to differentiate challenge and threat states, with relatively higher cardiac output and/or lower total peripheral resistance reactivity more reflective of a challenge state (Seery, 2011). While heart rate and cardiac output were estimated directly by the Physioflow, total peripheral resistance was calculated using the formula [mean arterial pressure x 80 / cardiac output] (Sherwood, Allen, Fahrenberg, Kelsey, Lovallo, & van Doornen, 1990). Mean arterial pressure was calculated using the formula [(2 x diastolic blood pressure) + systolic blood pressure / 3] (Cywinski, 1980). Unfortunately, due to technical issues, cardiovascular data could not be recorded for one participant before trial one and six participants before trial two.

>>>>>>>>>>Table 1 Near Here<<<<<<<<<<

Attentional control. Gaze behavior was measured using a SensoMotoric Instruments (SMI; Boston, MA) mobile eye tracker. This lightweight (76.0 g) binocular system uses dark pupil tracking to calculate point of gaze and record the visual scene at a spatial resolution of 0.5° and a temporal resolution of 30.0 Hz. Gaze was monitored in real time using a laptop (Lenovo, ThinkPad) installed with iViewETG software. Participants were connected to the laptop via a 3.8 m USB cable, and the researcher and laptop were located behind the participant to minimize distractions. Before the first trial of the pressurized soccer penalty task, the mobile eye tracker was calibrated by asking participants to focus on all four corners of the goal sequentially (Wilson et al., 2009). Gaze behavior was recorded for subsequent offline analysis. Unfortunately, due to technical issues with the mobile eye tracker, gaze behavior could not be recorded for one participant.

Gaze data was analyzed frame-by-frame using quiet eye solutions software (www.quieteyesolutions.com). A fixation was defined as a gaze that was maintained on a location within 1.0° of a visual angle for at least 120.0 ms (Vickers, 2007). Four gaze measures were assessed for each participant during trial one of the pressurized soccer penalty task. These included: (1) quiet eye duration, (2) search rate, (3) total number of fixations, and (4) total fixation duration. Quiet eye duration referred to the length of the final fixation on the ball (in ms) before initiation of the run-up (Wood & Wilson, 2011). Search rate was calculated by dividing the total number of fixations by the total duration of fixations towards all key locations (in seconds; Nibbeling, Oudejans, & Daanen, 2012). The total number of fixations referred to the frequency with which participants fixated the goalkeeper, goal (e.g., net, posts, crossbar), ball, or other (e.g., ground) locations (Wilson et al., 2009). Finally, total fixation duration was calculated as the total (cumulative) time participants spent fixating each of these four locations (in ms; Wilson et al., 2009).

Task performance. The accuracy of the first trial of the pressurized soccer penalty task was measured in terms of horizontal distance from the centre of the goal (in cm) by frame-by-frame analysis of the gaze footage using quiet eye solutions software (www.quieteyesolutions.com; Wilson et al., 2009). The centre of the goal was marked as the ‘origin’, with six 30 cm zones either side of this point reaching a maximum 180 cm at either post. Higher scores thus reflected a more accurate penalty placed further from the goalkeeper (Van der Kamp, 2006). Penalties that hit the post (n = 2), crossbar (n = 1), goalkeeper (n = 1), or missed the goal (n = 7), were given a score of zero.

Procedure

After arriving at the laboratory, participants read an information sheet, gave written informed consent, and provided demographic information (e.g., age, gender, and soccer experience). Next, participants were fitted with the Physioflow and mobile eye tracker, which were both calibrated. Participants were then asked to remain still, quiet, and seated for five minutes while baseline cardiovascular data was recorded. Next, participants received verbal instructions designed to elevate pressure (Baumeister & Showers, 1986). These instructions highlighted (1) the importance of the task and an accurate penalty, (2) that the goalkeeper would attempt to save the penalty, (3) that their performance would be placed on a leader board, (4) that the five most accurate participants would receive a prize, (5) that the five least accurate participants would be interviewed at length about their poor performance, and (6) that all penalties would be recorded on a digital video camera and scrutinized by a soccer penalty expert. Next, cardiovascular data was recorded for another minute while participants reflected on these instructions and thought about the upcoming task. Participants then completed the two self-report items assessing demand and resource evaluations. The calibration of the mobile eye tracker was then checked, and re-calibrated if necessary, before participants completed the pressurized soccer penalty task. This procedure was then repeated for a second trial. To help ensure that the second trial was also pressurized, some of the instructions used in the first trial were adapted, informing participants that their performance on the second trial would be combined with their performance on the first trial, and then placed on to a leader board to allocate prizes and interviews. Finally, participants were debriefed and thanked for their participation.

Data Processing and Statistical Analysis

A single challenge/threat index (CTI) was created for both trials by converting cardiac output and total peripheral resistance reactivity values into z-scores and summing them. Cardiac output was assigned a weight of +1, while total peripheral resistance was allocated a weight of -1 (reverse scored), such that higher values corresponded with cardiovascular responses more reflective of a challenge state (i.e., higher cardiac output and/or lower total peripheral resistance reactivity; Seery, 2011). Before the final analyses, data with *z*-scores greater than two were removed (Moore, Young, Freeman, & Sarkar, 2017). These outlier analyses were employed as more conservative approaches did not ensure that all data were normally distributed (e.g., winsorization). The two *z*-score approach resulted in three values being removed for each of trial one CTI, total number of fixations on the goalkeeper, ball and other, and the total fixation duration on the goalkeeper and other. In addition, two values were removed for each of trial one heart rate reactivity, quiet eye duration, total number of fixations on the goal, and total fixation duration on the goal. Finally, one value was removed for trial two CTI. Following these outlier analyses, all data were normally distributed (i.e., skewness and kurtosis did not exceed 1.96).

To assess task engagement before the first and second trials of the pressurized soccer penalty task, dependent *t*-tests were conducted to establish that in the sample as a whole, heart rate increased significantly from the baseline time periods (i.e., heart rate reactivity greater than zero; Seery, Weisbuch, & Blascovich, 2009). Next, descriptive statistics and bivariate correlations were calculated (Table 2). A series of bivariate regression analyses were then conducted to examine the extent to which challenge and threat states, assessed via both demand and resource evaluations and cardiovascular reactivity (i.e., DRES and CTI, analyzed separately), predicted task performance (i.e., soccer penalty accuracy), and attentional control (i.e., quiet eye duration, search rate, total number of fixations, and total fixation durations), during the first trial of the pressurized soccer penalty task. Following this, forced entry multiple regression analyses were conducted, with DRES and CTI entered together to determine which (if any) was the strongest predictor. Next, to examine if any of the attentional variables mediated the relationship between DRES or CTI and task performance, mediation analyses were conducted using the Process SPSS custom dialog (Hayes, 2018). This custom dialog tests the total, direct, and indirect effect of an independent variable on a dependent variable through a proposed mediator, and allows inferences regarding indirect effects using percentile bootstrap confidence intervals. Finally, hierarchical multiple regression analyses were performed to assess if CTI, total fixation duration on the goalkeeper, and task performance during the first trial of the pressurized soccer penalty task, predicted DRES and CTI before the second trial, over and above the effects of trial one DRES or CTI. A *p*-value of less than .05 was deemed statistically significant (Field, 2013). All statistical analyses were conducted using IBM SPSS statistics v.22.

Results

>>>>>>>>>>Table 2 Near Here<<<<<<<<<<

Task Engagement

Heart rate increased significantly from baseline by an average of 9.49 (SD = 4.78) beats per minute before trial one ($t(38) = 15.13$, $p < .001$), and an average of 8.40 (SD = 3.16) beats per minute before trial two ($t(36) = 15.96$, $p < .001$), confirming task engagement and enabling further examination of challenge and threat states during both trials (via DRES and CTI).

Trial One

Task performance. Bivariate regression analyses revealed that both DRES ($R^2 = .11$) and CTI ($R^2 = .28$) significantly predicted task performance. Thus, participants who evaluated the task as more of a challenge, and displayed a cardiovascular response more representative of a challenge state, performed more accurately than participants who evaluated the task as more of a threat, and displayed a cardiovascular response more representative of a threat state. However, multiple regression analyses revealed that only CTI significantly predicted task performance (Table 3).

>>>>>>>>>>Table 3 Near Here<<<<<<<<<<

Attentional control.

Quiet eye duration. Bivariate regression analyses revealed that DRES ($R^2 = -.08$) did not significantly predict quiet eye duration. However, CTI ($R^2 = .69$) was a significant predictor, suggesting that participants who exhibited a cardiovascular response more indicative of a challenge state displayed longer quiet eye durations than participants who exhibited a cardiovascular response more typical of a threat state. Indeed, multiple regression analyses confirmed that only CTI significantly predicted quiet eye duration (Table 3).

Search rate. Bivariate regression analyses revealed that DRES (R^2 = .03) did not significantly predict search rate. However, CTI (R^2 = .19) was a significant predictor, implying that participants who displayed a cardiovascular response more akin to a challenge state exhibited lower search rates than participants who displayed a cardiovascular response more indicative of a threat state. Indeed, multiple regression analyses confirmed that only CTI significantly predicted search rate (Table 3).

Total number of fixations.

Total number of fixations – goalkeeper. Bivariate regression analyses revealed that neither DRES (R^2 = .05) nor CTI (R^2 = .02) significantly predicted the number of fixations towards the goalkeeper. This was confirmed by the multiple regression analyses (Table 3).

Total number of fixations – goal. Bivariate regression analyses revealed that DRES (R^2 = -.02) did not significantly predict the number of fixations towards the goal. However, CTI (R^2 = .08) approached significance, suggesting that participants who exhibited a cardiovascular response more akin to a challenge state tended to direct more fixations towards the goal compared to participants who displayed a cardiovascular response more akin to a threat state. Multiple regression analyses confirmed that only CTI marginally predicted the number of fixations towards the goal (Table 3).

Total number of fixations – ball. Bivariate regression analyses revealed that DRES (R^2 = -.02) did not significantly predict the number of fixations towards the ball, but CTI (R^2 = .09) was a significant predictor. Thus, participants who displayed a cardiovascular response more representative of a challenge state directed more fixations towards the ball than participants who displayed a cardiovascular response more indicative of a threat state. However, multiple regression analyses revealed that CTI only marginally predicted the number of fixations on the ball (Table 3).

Total number of fixations – other. Bivariate regression analyses revealed that neither DRES (R^2 = .00) nor CTI (R^2 = -.03) significantly predicted the number of fixations towards other locations. This was confirmed by the multiple regression analyses (Table 3).

Total fixation duration.

Total fixation duration – goalkeeper. Bivariate regression analyses revealed that both DRES (R^2 = .16) and CTI (R^2 = .12) significantly predicted the time spent fixating on the goalkeeper. Thus, participants who evaluated the task as more of a challenge, and displayed a cardiovascular response more indicative of a challenge state, spent longer fixating on the goalkeeper than participants who evaluated the task as more of a threat, and displayed a cardiovascular response more reflective of a threat state. However, multiple regression analyses revealed that neither DRES nor CTI significantly predicted the time spent fixating on the goalkeeper (Table 3).

Total fixation duration – goal. Bivariate regression analyses revealed that DRES (R^2 = -.03) did not significantly predict the time spent fixating on the goal. However, CTI (R^2 = .09) was a significant predictor, suggesting that participants who displayed a cardiovascular response more indicative of a challenge state spent longer fixating on the goal compared to those who responded with a cardiovascular response more reflective of a threat state. Indeed, multiple regression analyses confirmed that only CTI significantly predicted the time spent fixating on the goal (Table 3).

Total fixation duration – ball. Bivariate regression analyses revealed that neither DRES (R^2 = -.02) nor CTI (R^2 = -.02) significantly predicted the time spent fixating on the ball. This was confirmed by the multiple regression analyses (Table 3).

Total fixation duration – other. Bivariate regression analyses revealed that DRES (R^2 = -.03) did not significantly predict the time spent fixating on other locations. However, CTI (R^2 = .09) was a significant predictor, implying that participants who exhibited a cardiovascular response more akin to a challenge state spent longer fixating on other areas of the display (e.g., ground) than participants who exhibited a cardiovascular response more akin to a threat state. Indeed, multiple regression analyses confirmed that only CTI significantly predicted the time spent fixating on other locations (Table 3).

Mediation analyses. To test for mediation, either DRES or CTI was entered as the independent variable, task performance was entered as the dependent variable, and quiet eye duration, search rate, total number of fixations, and total fixation durations were entered separately as potential mediators. Based on a 10,000 sampling rate, the results from bootstrapping revealed no significant indirect effects for any of the mediators with either DRES or CTI entered as the independent variable. This was because the 95% confidence intervals for all mediation analyses contained zero (Table 4). Thus, none of the attentional variables mediated the relationship between DRES or CTI and task performance.

>>>>>>>>>>Table 4 Near Here<<<<<<<<<<

Feedback Loops

DRES (Trial 2). Hierarchical regression analyses revealed that neither CTI (ΔR^2 = .01) nor time spent fixating the goalkeeper (ΔR^2 = .03) during the first trial significantly predicted DRES before the second trial, over and above the effects of trial one DRES (R^2 = .50). However, task performance (ΔR^2 = .02) marginally predicted DRES before the second trial, suggesting that participants who took a more accurate penalty during the first trial were more likely to evaluate the second trial as more of a challenge (Table 5).

CTI (Trial 2). Hierarchical regression analyses revealed that neither time spent fixating the goalkeeper (ΔR^2 = .05) nor task performance (ΔR^2 = .02) during the first trial significantly predicted CTI before the second trial, over and above the effects of trial one CTI (R^2 = .10) (Table 5).

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Discussion

A growing body of research has demonstrated that the psychophysiological states of challenge and threat predict sports performance under pressure (e.g., Moore et al., 2013; Turner et al., 2013). However, to date, relatively little research has examined the mechanisms underpinning the beneficial effects of a challenge state (Moore et al., 2012). Therefore, to aid theory and intervention development, as well as our understanding of the effects of psychophysiological responses to stress on sports performance, the present study provided an initial test of the predictions of the integrative framework of stress, attention, and visuomotor performance (Vine et al., 2016).

According to the integrative framework (Vine et al., 2016), and BPSM (Blascovich, 2008), a challenge state should lead to better sports performance than a threat state. As predicted, both subjective (i.e., DRES) and objective (i.e., CTI) measures of these states significantly predicted performance during the first trial of the pressurized soccer penalty task, equating to medium and large effect sizes, respectively. Specifically, participants who evaluated the task as more of a challenge (i.e., coping resources match or exceed task demands), and responded to the task with a cardiovascular response more reflective of a challenge state (i.e., relatively higher cardiac output and/or lower total peripheral resistance reactivity), took a more accurate penalty that was placed further from the goalkeeper and closer to the goalpost. These findings add to previous research suggesting that a challenge state is optimal for sports performance under pressure (e.g., Blascovich et al., 2004; Turner et al., 2012). For example, Moore and colleagues (2013) found that golfers who evaluated a golf competition as a more of a challenge shot lower scores than golfers who viewed it as more of a threat. Moreover, Turner et al. (2013) found that cricketers who responded to a cricket batting test with a cardiovascular response more akin to a challenge state scored more runs than cricketers who reacted with more of a threat-like cardiovascular response. Interestingly, in the present study, when CTI and DRES were analyzed together, only CTI significantly predicted performance, suggesting that the cardiovascular response accompanying a challenge state might be a more powerful predictor of sports performance than self-reported evaluations of task demands and personal coping resources.

To explain how a challenge state benefits performance, the integrative framework draws upon two attentional systems first outlined by Corbetta and Schulman (2002), the goal-directed and stimulus-driven systems. Specifically, the framework suggests that these systems are balanced during a challenge state, allowing athletes to remain focused on the most salient task-relevant cues and process the optimal visual information needed to accurately perform the task (Vine et al., 2016). In contrast, during a threat state, the stimulus-driven system overrides the goal-directed system, causing athletes to become distracted by less relevant (and potentially threatening) stimuli, stopping them from processing the information needed to execute the task optimally (Vine et al., 2016). This study offered some support for these predictions, demonstrating that participants who reacted to the task with more of a challenge-like cardiovascular response displayed longer quiet eye durations and lower search rates, as well as marginally more fixations towards the goal and ball, and longer fixations on the goal and other areas of the display (e.g., ground). Crucially, both longer quiet eye durations and lower search rates are considered indexes of optimal goal-directed attention (e.g., Wilson, Vine, & Wood, 2009), and more fixations towards the goal and ball, and longer fixations on the goal and other locations (e.g., ground), have been linked with better spatial calibration and accuracy in soccer penalties (Kuntz, Hegele, & Munzert, 2018). However, mediation analyses revealed that none of these attentional variables could explain the relationship between challenge and threat states (i.e., DRES or CTI) and task performance. Thus, although these states appeared to have different effects on attentional control, these differences did not appear to impact upon performance. Clearly more research is needed to elucidate other possible underlying mechanisms (e.g., kinematic).

Despite the absence of mediation, the above results support research that has shown that challenge and threat states have divergent effects on attentional control (Moore et al., 2012; Vine et al., 2013). For example, Moore et al. (2013) found that golfers who were manipulated into a challenge state displayed longer quiet eye durations, and thus superior goal-directed attention. Further, Vine et al. (2015) found that pilots who evaluated a stressful task as a challenge displayed lower search rates, and thus less stimulus-driven attention. Notwithstanding this research, little work has investigated the integrative framework’s prediction that a threat state is linked with hypervigilance to threatening cues (Frings et al., 2014). This study tested this assumption by examining the link between challenge and threat states and the number of fixations towards, and the total time spent fixating, the goalkeeper (i.e., threatening stimuli). While neither DRES nor CTI predicted the number of fixations, both predicted the time spent fixating the goalkeeper. However, these results were not in the predicted direction. Specifically, participants who evaluated the task as more of a challenge, and responded with a more challenge-like cardiovascular response, fixated the goalkeeper for longer. Although research has shown that anxiously fixating the goalkeeper is a suboptimal strategy that can result in kicks finishing closer to the goalkeeper (e.g., Noel & Van der Kamp, 2012), participants who experienced a challenge state might have offset this effect by employing longer quiet eye durations, more fixations towards the goal and ball, and fixating the goal for longer. Indeed, research has highlighted that fixating these key locations is vital for penalty kick preparation (Kurtz et al., 2018). It should also be noted that a keeper-dependant strategy is commonly used by soccer players (Kuhn, 1988), but the predictive design used in this study makes it difficult to separate strategic from pressure-related effects. Interestingly, when DRES and CTI were analyzed together, neither predicted the time spent looking at the goalkeeper, suggesting that further research is needed to examine if challenge and threat states are associated with hypervigilance to threatening cues.

The integrative framework also makes predictions about the self-perpetuating nature of challenge and threat states, suggesting that a cardiovascular response more congruent with a threat state, greater attention to threatening stimuli, and poorer performance during a sporting task, all increase the likelihood that similar tasks will be evaluated as a threat (i.e., task demands exceed coping resources) in the future (Vine et al., 2016). However, to date, little research has tested these feedback loops, and the results of this study offered only limited support. First, while trial one CTI marginally predicted trial two CTI, suggesting some stability in the cardiovascular responses accompanying challenge and threat states, trial one CTI did not predict DRES before the second trial. This null finding might be due to social desirability bias emanating from the participants who responded to the first trial with a threat-like cardiovascular response trying to appear more confident before the second trial (Weisbuch, Seery, Ambady, & Blascovich, 2009). Second, time spent fixating the goalkeeper during the first trial did not predict DRES or CTI before the second trial, possibly owing to the goalkeeper being used to prepare the penalty rather than being viewed as a threatening cue (as noted above). Third, performance during the first trial did not predict CTI before the second trial, however, performance did marginally predict DRES, suggesting that participants who performed the first trial less accurately tended to evaluate the second trial as more of a threat (or vice versa). This finding contradicts previous research (Quigley et al., 2002), and suggests that prior performance might influence future demand and resource evaluations. Indeed, past success (or failure) may promote a challenge (or threat) state by promoting (or reducing) self-efficacy (Jones et al., 2009).

The results of this study have some important implications. First, from a theoretical perspective, they suggest that the integrative framework of stress, attention, and visuomotor performance (Vine et al., 2016) might hold some promise in understanding the effects of psychophysiological responses to stress (i.e., challenge and threat states) on sports performance, as well as the influence of prior performance on future psychological reactions to stress. However, the results also raise questions about some of the predictions of this framework, and suggest that further research is needed to investigate if (1) attentional control mediates the relationship between challenge and threat states and sports performance, (2) a challenge or threat state is linked with hypervigilance to threatening cues, and (3) whether cardiovascular responses and attentional control during a task influence challenge and threat responses to similar tasks in the future (Vine et al., 2016). Second, from an applied viewpoint, the findings suggest that encouraging athletes to respond to stress in a manner consistent with a challenge state might benefit performance. Indeed, interventions aimed at reducing the evaluated demands of the situation and the perceived or actual coping resources of athletes might accomplish this. While interventions such as imagery scripts (e.g., Williams, Cumming, & Balanos, 2010) and arousal reappraisal (e.g., Moore, Vine, Wilson, & Freeman, 2015) have been shown to promote a challenge state, more research is needed to identify other strategies that practitioners could utilize in applied settings (e.g., self-talk; Tod, Hardy, & Oliver, 2011).

Despite the novel results of this study, several limitations should be noted and used to guide future research. First, the use of experienced rather than elite soccer players could be seen as a limitation, restricting the generalizability of the findings. Given that knowledge, skills, and ability are proposed to influence challenge and threat states (Blascovich, 2008), future research should try to replicate this study using a more elite sample (Swann, Moran, & Piggott, 2015). Indeed, to date, relatively little work has explored the relationship between challenge and threat states and performance among elite athletes (see Turner et al., 2013 for a possible exception). Second, the relatively low number of female participants prevented an examination of possible gender differences in challenge and threat states, attentional control, and visuomotor performance. While this might be viewed as a limitation, it should be noted that the integrative framework makes no predictions relating to gender (Vine et al., 2016). However, given that some studies have shown small gender differences (e.g., Quigley et al., 2002), future research should examine if gender influences challenge and threat states during sporting competition. Third, measuring performance via a single trial might be seen as a limitation, decreasing the validity and reliability of the results. However, given that athletes' often only have one opportunity to succeed or fail during high-pressure competition, a single-trial was used to enhance ecological validity and psychological pressure. That said, future research is encouraged to replicate this study using multiple trials and during real competition (Moore et al., 2013).

Conclusion

The results demonstrate that psychophysiological responses to stress are associated with sports performance and attentional control under pressure, with a challenge state linked with better performance and more optimal goal-directed attentional control than a threat state. However, attentional control failed to mediate relationship between challenge and threat states and sports performance, highlighting that more research is needed to illuminate potential underlying mechanisms. Finally, the results imply that the relationship between challenge and threat states and sports performance might be reciprocal, with poorer performance possibly leading to subsequent tasks being viewed as more of a threat (or vice versa). Thus, to maximize performance under pressure, practitioners should help their athletes respond to stressful competition with a challenge state.

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Table 1

Means and standard deviations for heart rate, cardiac output, and total peripheral resistance estimated during the baseline and post-instruction time periods before the first and second trials of the pressurized soccer penalty task.

	Trial One				Trial Two			
	Baseline		Post-Instruction		Baseline		Post-Instruction	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Heart rate	68.31	12.39	77.80	12.00	67.90	11.19	76.30	10.58
Cardiac output	6.83	1.17	7.75	1.49	7.08	1.29	7.73	1.41
Total peripheral resistance	1147.91	178.59	1017.63	167.71	1106.61	198.26	1012.45	169.69

Table 2

Means, standard deviations, and correlations for all variables.

	Mean	SD	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1. DRES (Trial 1)	1.57	2.07		.31	.36*	.21	-.22	.27	.06	.08	-.17	.43**	-.00	.09	-.01	.76**	.34
2. CTI (Trial 1)	-0.34	1.51			.55**	.86*	-.46**	.22	.33	.34*	.00	.38*	.35*	.09	.34*	.13	.33
3. Task performance	77.31	57.75				.25	-.29	.14	.15	.17	-.04	.22	.17	.11	.10	.40**	.15
4. Quiet eye duration	184.00	65.86					-.19	.24	.05	.05	.10	.31	.07	-.20	.39	.25	.40
5. Search rate	4.63	1.22						-.32*	-.29	-.29	.20	-.39*	-.48**	-.47**	-.24	-.07	-.33
6. Number of fixations - goalkeeper	1.84	1.05							.07	.09	.04	.80**	.03	.25	.17	.05	-.11
7. Number of fixations - goal	2.92	1.83								.99**	.16	.15	.89**	.11	.40*	-.10	.23
8. Number of fixations - ball	2.89	1.84									.14	.17	.89**	.08	.39*	-.08	.23
9. Number of fixations - other	10.92	3.89										-.19	.09	.05	.69**	-.19	-.17
10. Fixation duration - goalkeeper	451.58	347.83											.15	.13	.09	.16	.10
11. Fixation duration - goal	663.59	475.04												.23	.46**	-.13	.33
12. Fixation duration - ball	2241.95	1537.24													.25	.01	.17
13. Fixation duration - other	2202.11	987.97														-.13	.25
14. DRES (Trial 2)	1.69	2.09															.32
15. CTI (Trial 2)	-0.31	1.45															

Notes. * Denotes correlation significant at .05 level (2-tailed), ** Denotes correlation significant at .01 level (2-tailed)

Table 3

Bivariate and forced entry multiple regression analyses (models 1 and 2, respectively), reporting the variance in task performance, quiet eye duration, search rate, total number of fixations, and total fixation durations by DRES and CTI.

		Model 1				Model 2			
Dependent variable	Independent variable	*B*	*SE B*	*t*	95% CI	*B*	*SE B*	*t*	95% CI
Task performance	DRES	9.93	4.12	2.41	1.61, 18.24*	5.60	4.09	1.37	-2.70, 13.90
	CTI	21.09	5.40	3.91	10.14, 32.05***	18.68	5.62	3.33	7.28, 30.09**
Quiet eye duration	DRES	6.58	10.96	0.60	-18.68, 31.85	-4.67	9.01	-0.52	-29.70, 20.36
	CTI	36.18	9.51	3.80	11.73, 60.63*	39.06	11.70	3.34	6.58, 71.53*
Search rate	DRES	-0.13	0.09	-1.43	-0.31, 0.05	-0.07	0.09	-0.73	-0.25, 0.12
	CTI	-0.36	0.12	-3.03	-0.60, -0.12**	-0.33	0.13	-2.62	-0.59, -0.07*
Number of fixations - goalkeeper	DRES	0.14	0.09	1.68	-0.03, 0.32	0.13	0.09	1.34	-0.07, 0.32
	CTI	0.15	0.12	1.27	-0.09, 0.39	0.10	0.12	0.83	-0.15, 0.35
Number of fixations - goal	DRES	0.06	0.14	0.38	-0.24, 0.35	-0.07	0.16	-0.42	-0.39, 0.26
	CTI	0.43	0.21	2.02	0.00, 0.87^	0.46	0.23	2.02	0.00, 0.93^
Number of fixations - ball	DRES	0.07	0.15	0.46	-0.23, 0.36	-0.06	0.16	-0.34	-0.39, 0.28
	CTI	0.45	0.22	2.06	0.01, 0.89*	0.47	0.23	2.03	0.00, 0.94^
Number of fixations - other	DRES	-0.32	0.30	-1.05	-0.92, 0.29	-0.32	0.33	-0.97	-1.00, 0.36
	CTI	0.01	0.44	0.02	-0.88, 0.90	0.15	0.46	0.33	0.79, 1.09
Fixation duration - goalkeeper	DRES	72.14	25.42	2.84	20.59, 123.69**	46.40	27.30	1.70	-9.21, 102.00
	CTI	82.74	35.15	2.35	11.22, 154.25*	64.82	35.78	1.81	-8.05, 137.70
Fixation duration - goal	DRES	-0.37	36.77	-0.01	-74.86, 74.13	-37.33	41.47	-0.90	-121.80, 47.134
	CTI	115.58	54.24	2.13	5.23, 225.92*	135.35	58.66	2.31	15.87, 254.83*
Fixation duration - ball	DRES	68.39	116.85	0.59	-167.97, 304.75	21.43	130.77	0.16	-244.32, 287.17
	CTI	86.39	168.88	0.51	-256.45, 429.24	76.95	180.71	0.43	-290.31, 444.21
Fixation duration - other	DRES	-2.92	77.49	-0.04	-160.07, 154.23	-75.54	78.71	-0.96	-236.07, 84.98
	CTI	211.41	102.17	2.07	3.30, 419.51*	245.71	108.36	2.27	24.72, 466.71*

*Notes.** $p < .05$, ** $p < .01$, *** $p < .001$, ^ $p < .06$

Table 4

Mediational analyses with DRES or CTI before the first trial of the pressurized soccer task entered as the independent variable, task performance during the first trial of the task entered as the dependent variable, and quiet eye duration, search rate, total number of fixations, or total fixation durations entered separately as potential mediators.

Mediator	Independent variable	Effect	*SE*	95% CI
Quiet eye duration	DRES	1.22	7.50	-4.05, 38.81
	CTI	-14.45	18.60	-41.90, 20.79
Search rate	DRES	1.38	1.38	-0.32, 5.63
	CTI	-0.43	2.70	-5.92, 5.09
Number of fixations - goalkeeper	DRES	0.51	1.66	-1.48, 5.32
	CTI	-0.12	1.84	-4.84, 3.17
Number of fixations - goal	DRES	0.23	0.99	-1.01, 3.46
	CTI	-0.42	2.40	-6.49, 3.77
Number of fixations - ball	DRES	0.31	1.08	-0.90, 4.20
	CTI	-0.29	2.52	-5.94, 4.69
Number of fixations - other	DRES	-0.13	1.06	-3.21, 1.49
	CTI	0.00	0.73	-1.56, 1.54
Fixation duration - goalkeeper	DRES	1.17	2.58	-2.72, 7.61
	CTI	-0.08	3.24	-7.06, 6.73
Fixation duration - goal	DRES	-0.01	0.98	-2.15, 1.97
	CTI	-0.80	2.14	-6.31, 2.71
Fixation duration - ball	DRES	0.20	0.79	-0.70, 3.06
	CTI	-0.07	0.81	-2.54, 0.97
Fixation duration - other	DRES	-0.02	0.71	-1.63, 1.32
	CTI	0.30	2.05	-2.79, 5.86

Note. No indirect effects were significant

Table 5

Hierarchical multiple regression analyses, reporting the variance in DRES and CTI before the second trial of the pressurized soccer penalty task explained by CTI, total fixation duration on the goalkeeper, and task performance during the first trial, over and above trial one DRES or CTI.

Dependent variable	Independent variable	Step	*B*	*SE B*	*t*	95% CI
DRES (Trial 2)	DRES (Trial 1)	1	0.71	0.12	5.87	0.46, 0.95***
	CTI (Trial 1)	2	-0.24	0.19	-1.26	-0.62, 0.15
	Fixation duration - goalkeeper	2	-0.00	0.00	-1.43	-0.00, 0.00
	Task performance	2	0.01	0.01	1.92	-0.00, 0.02^
CTI (Trial 2)	CTI (Trial 1)	1	0.34	0.17	2.04	-0.00, 0.68^
	Fixation duration - goalkeeper	2	-0.00	0.00	-1.26	-0.00, 0.00
	Task performance	2	-0.00	0.00	-0.76	-0.01, 0.01

Notes. * $p < .05$, ** $p < .01$, *** $p < .001$, ^ $p < .07$