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

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Jack Brimmell, John Parker, Mark Wilson, Samuel Vine, & Lee Moore.
2018.

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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

57

Introduction

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

66

67

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

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

82

83 Distinct neuroendocrine and cardiovascular patterns are predicted to result from these demand
84 and resource evaluations (Blascovich, Vanman, Mendes, & Dickerson, 2011). When athletes evaluate
a stressful situation as a challenge, this triggers elevated sympathetic-adrenomedullary activation and

85 the release of catecholamines such as epinephrine and norepinephrine. Consequently, cardiac activity
86 increases (evidenced by elevations in cardiac output), blood vessels dilate (indexed by reductions in
87 total peripheral resistance), and more oxygenated blood is transported to the brain and muscles (Seery,
88 2011). Conversely, when athletes evaluate a stressful situation as a threat, this evokes pituitary-
89 adrenocortical activation and the release of cortisol, which attenuates sympathetic-adrenomedullary
90 activation. Subsequently, cardiac activity reduces (evidenced by little change or small decreases in
91 cardiac output), dilation of the blood vessels is inhibited (indexed by little change or small increases
92 in total peripheral resistance), and less blood flows to the brain and muscles (Seery, 2011). Thus,
93 compared to a threat state, a challenge state is marked by a cardiovascular response consisting of
94 relatively higher cardiac output and/or lower total peripheral resistance (Seery, 2011). These
95 cardiovascular indices have been extensively validated (Blascovich et al., 2011). For example,
96 Tomaka, Blascovich, Kibler and Ernst (1997) found that participants who received ‘challenge’
97 instructions evaluated a mental arithmetic task as more of a challenge (i.e., coping resources exceed
98 task demands), and displayed more of a challenge-like cardiovascular response (i.e., greater cardiac
99 output and lower total peripheral resistance), compared to those who received ‘threat’ instructions.

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

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

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

141 points (i.e., negative stimuli) than participants who were manipulated into a challenge state. Thus,
142 more research is required to test this, and the other core predictions, of the integrative framework.

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

156 **The present study**

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

165 It was hypothesized that participants who evaluated the task as more of a challenge (i.e.,
166 coping resources match or exceed task demands), and responded to the task with a cardiovascular
167 response more consistent with a challenge state (i.e., relatively higher cardiac output and/or lower
168 total peripheral resistance reactivity), would perform the task more accurately and display more

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

181 **Method**

182 **Participants**

183 A power analysis using G*Power software (Faul, Erdfelder, Lang, & Butchner, 2007)
184 revealed that, based on the large ($\beta = .64$) and medium ($\beta = .37$) effect sizes reported by Turner and
185 colleagues (2012; 2013), between 13 and 52 participants were required to achieve a power of .80,
186 given an alpha of .05. Thus, forty-two participants (35 male, 7 female; $M_{\text{age}} = 23.50$ years, $SD = 6.62$)
187 took part in the study. All participants had a minimum of two years' soccer experience ($M_{\text{experience}} =$
188 12.43 years, $SD = 6.53$). Furthermore, all participants reported being non-smokers, free of illness,
189 injury, or infection, having no known family history of cardiovascular or respiratory disease, having
190 not performed vigorous exercise or ingested alcohol within the last 24 hours, and having not
191 consumed food or caffeine within the last hour. Participants were tested individually. Before testing,
192 institutional ethical approval was obtained, and participants provided written informed consent.

193 **Task Setup**

194 The experimental task was adapted from previous research (e.g., Wilson et al., 2009), and
195 comprised a single kick of a standard indoor soccer ball (20.57 cm diameter) from a penalty spot

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

207 **Measures**

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

221 **Cardiovascular measures.** A non-invasive impedance cardiograph device (Physioflow
222 Enduro, Manatec Biomedical, Paris, France) was used to estimate heart rate (i.e., number of heart
223 beats per minute), cardiac output (i.e., amount of blood ejected from the heart in liters per minute),

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

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

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

253

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

264 Gaze data was analyzed frame-by-frame using quiet eye solutions software
265 (www.quieteyesolutions.com). A fixation was defined as a gaze that was maintained on a location
266 within 1.0° of a visual angle for at least 120.0 ms (Vickers, 2007). Four gaze measures were assessed
267 for each participant during trial one of the pressurized soccer penalty task. These included: (1) quiet
268 eye duration, (2) search rate, (3) total number of fixations, and (4) total fixation duration. Quiet eye
269 duration referred to the length of the final fixation on the ball (in ms) before initiation of the run-up
270 (Wood & Wilson, 2011). Search rate was calculated by dividing the total number of fixations by the
271 total duration of fixations towards all key locations (in seconds; Nibbeling, Oudejans, & Daanen,
272 2012). The total number of fixations referred to the frequency with which participants fixated the
273 goalkeeper, goal (e.g., net, posts, crossbar), ball, or other (e.g., ground) locations (Wilson et al.,
274 2009). Finally, total fixation duration was calculated as the total (cumulative) time participants spent
275 fixating each of these four locations (in ms; Wilson et al., 2009).

276 **Task performance.** The accuracy of the first trial of the pressurized soccer penalty task was
277 measured in terms of horizontal distance from the centre of the goal (in cm) by frame-by-frame
278 analysis of the gaze footage using quiet eye solutions software (www.quieteyesolutions.com; Wilson

279 et al., 2009). The centre of the goal was marked as the ‘origin’, with six 30 cm zones either side of
280 this point reaching a maximum 180 cm at either post. Higher scores thus reflected a more accurate
281 penalty placed further from the goalkeeper (Van der Kamp, 2006). Penalties that hit the post ($n = 2$),
282 crossbar ($n = 1$), goalkeeper ($n = 1$), or missed the goal ($n = 7$), were given a score of zero.

283 **Procedure**

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

303 **Data Processing and Statistical Analysis**

304 A single challenge/threat index (CTI) was created for both trials by converting cardiac output
305 and total peripheral resistance reactivity values into z -scores and summing them. Cardiac output was

306 assigned a weight of +1, while total peripheral resistance was allocated a weight of -1 (reverse
307 scored), such that higher values corresponded with cardiovascular responses more reflective of a
308 challenge state (i.e., higher cardiac output and/or lower total peripheral resistance reactivity; Seery,
309 2011). Before the final analyses, data with z -scores greater than two were removed (Moore, Young,
310 Freeman, & Sarkar, 2017). These outlier analyses were employed as more conservative approaches
311 did not ensure that all data were normally distributed (e.g., winsorization). The two z -score approach
312 resulted in three values being removed for each of trial one CTI, total number of fixations on the
313 goalkeeper, ball and other, and the total fixation duration on the goalkeeper and other. In addition, two
314 values were removed for each of trial one heart rate reactivity, quiet eye duration, total number of
315 fixations on the goal, and total fixation duration on the goal. Finally, one value was removed for trial
316 two CTI. Following these outlier analyses, all data were normally distributed (i.e., skewness and
317 kurtosis did not exceed 1.96).

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

361 state displayed longer quiet eye durations than participants who exhibited a cardiovascular response
362 more typical of a threat state. Indeed, multiple regression analyses confirmed that only CTI
363 significantly predicted quiet eye duration (Table 3).

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

369 ***Total number of fixations.***

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

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

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

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

388

389 ***Total fixation duration.***

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

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

403 *Total fixation duration – ball.* Bivariate regression analyses revealed that neither DRES ($R^2 =$
404 $-.02$) nor CTI ($R^2 = -.02$) significantly predicted the time spent fixating on the ball. This was
405 confirmed by the multiple regression analyses (Table 3).

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

413 ***Mediation analyses.*** To test for mediation, either DRES or CTI was entered as the
414 independent variable, task performance was entered as the dependent variable, and quiet eye duration,
415 search rate, total number of fixations, and total fixation durations were entered separately as potential
416 mediators. Based on a 10,000 sampling rate, the results from bootstrapping revealed no significant

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

463 To explain how a challenge state benefits performance, the integrative framework draws upon
464 two attentional systems first outlined by Corbetta and Schulman (2002), the goal-directed and
465 stimulus-driven systems. Specifically, the framework suggests that these systems are balanced during
466 a challenge state, allowing athletes to remain focused on the most salient task-relevant cues and
467 process the optimal visual information needed to accurately perform the task (Vine et al., 2016). In
468 contrast, during a threat state, the stimulus-driven system overrides the goal-directed system, causing
469 athletes to become distracted by less relevant (and potentially threatening) stimuli, stopping them
470 from processing the information needed to execute the task optimally (Vine et al., 2016). This study
471 offered some support for these predictions, demonstrating that participants who reacted to the task
472 with more of a challenge-like cardiovascular response displayed longer quiet eye durations and lower

473 search rates, as well as marginally more fixations towards the goal and ball, and longer fixations on
474 the goal and other areas of the display (e.g., ground). Crucially, both longer quiet eye durations and
475 lower search rates are considered indexes of optimal goal-directed attention (e.g., Wilson, Vine, &
476 Wood, 2009), and more fixations towards the goal and ball, and longer fixations on the goal and other
477 locations (e.g., ground), have been linked with better spatial calibration and accuracy in soccer
478 penalties (Kuntz, Hegele, & Munzert, 2018). However, mediation analyses revealed that none of these
479 attentional variables could explain the relationship between challenge and threat states (i.e., DRES or
480 CTI) and task performance. Thus, although these states appeared to have different effects on
481 attentional control, these differences did not appear to impact upon performance. Clearly more
482 research is needed to elucidate other possible underlying mechanisms (e.g., kinematic).

483 Despite the absence of mediation, the above results support research that has shown that
484 challenge and threat states have divergent effects on attentional control (Moore et al., 2012; Vine et
485 al., 2013). For example, Moore et al. (2013) found that golfers who were manipulated into a challenge
486 state displayed longer quiet eye durations, and thus superior goal-directed attention. Further, Vine et
487 al. (2015) found that pilots who evaluated a stressful task as a challenge displayed lower search rates,
488 and thus less stimulus-driven attention. Notwithstanding this research, little work has investigated the
489 integrative framework's prediction that a threat state is linked with hypervigilance to threatening cues
490 (Frings et al., 2014). This study tested this assumption by examining the link between challenge and
491 threat states and the number of fixations towards, and the total time spent fixating, the goalkeeper
492 (i.e., threatening stimuli). While neither DRES nor CTI predicted the number of fixations, both
493 predicted the time spent fixating the goalkeeper. However, these results were not in the predicted
494 direction. Specifically, participants who evaluated the task as more of a challenge, and responded with
495 a more challenge-like cardiovascular response, fixated the goalkeeper for longer. Although research
496 has shown that anxiously fixating the goalkeeper is a suboptimal strategy that can result in kicks
497 finishing closer to the goalkeeper (e.g., Noel & Van der Kamp, 2012), participants who experienced a
498 challenge state might have offset this effect by employing longer quiet eye durations, more fixations
499 towards the goal and ball, and fixating the goal for longer. Indeed, research has highlighted that
500 fixating these key locations is vital for penalty kick preparation (Kurtz et al., 2018). It should also be

501 noted that a keeper-dependant strategy is commonly used by soccer players (Kuhn, 1988), but the
502 predictive design used in this study makes it difficult to separate strategic from pressure-related
503 effects. Interestingly, when DRES and CTI were analyzed together, neither predicted the time spent
504 looking at the goalkeeper, suggesting that further research is needed to examine if challenge and
505 threat states are associated with hypervigilance to threatening cues.

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

525 The results of this study have some important implications. First, from a theoretical
526 perspective, they suggest that the integrative framework of stress, attention, and visuomotor
527 performance (Vine et al., 2016) might hold some promise in understanding the effects of
528 psychophysiological responses to stress (i.e., challenge and threat states) on sports performance, as

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

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

557 to enhance ecological validity and psychological pressure. That said, future research is encouraged to
558 replicate this study using multiple trials and during real competition (Moore et al., 2013).

559 **Conclusion**

560 The results demonstrate that psychophysiological responses to stress are associated with
561 sports performance and attentional control under pressure, with a challenge state linked with better
562 performance and more optimal goal-directed attentional control than a threat state. However,
563 attentional control failed to mediate relationship between challenge and threat states and sports
564 performance, highlighting that more research is needed to illuminate potential underlying
565 mechanisms. Finally, the results imply that the relationship between challenge and threat states and
566 sports performance might be reciprocal, with poorer performance possibly leading to subsequent tasks
567 being viewed as more of a threat (or vice versa). Thus, to maximize performance under pressure,
568 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
8. Number of fixations - ball	2.89	1.84										.14	.17	.89**	.08	.39*	-.08
9. Number of fixations - other	10.92	3.89											-.19	.09	.05	.69**	-.19
10. Fixation duration - goalkeeper	451.58	347.83												.15	.13	.09	.16
11. Fixation duration - goal	663.59	475.04													.23	.46**	-.13
12. Fixation duration - ball	2241.95	1537.24														.25	.01
13. Fixation duration - other	2202.11	987.97															-.13
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.

Dependent variable	Independent variable	Model 1				Model 2			
		<i>B</i>	<i>SE B</i>	<i>t</i>	95% CI	<i>B</i>	<i>SE B</i>	<i>t</i>	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

Mediation 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	<i>B</i>	<i>SE B</i>	<i>t</i>	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. * $p < .05$, ** $p < .01$, *** $p < .001$, ^ $p < .07$