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Champ or chump? Challenge and threat states during pressurized competition

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Abstract

The present research examined the immediate impact of challenge and threat states on golf performance in both real competition and a laboratory-based task. In study 1, one hundred and ninety-nine experienced golfers reported their evaluations of competition demands and personal coping resources before a golf competition. Evaluating the competition as a challenge (i.e., sufficient resources to cope with demands) was associated with superior performance. In study 2, sixty experienced golfers randomly received challenge or threat manipulation instructions and then performed a competitive golf putting task. Challenge and threat states were successfully manipulated and the challenge group outperformed the threat group. Furthermore, the challenge group reported less anxiety, more facilitative interpretations of anxiety, less conscious processing, and displayed longer quiet eye durations. However, these variables failed to mediate the group-performance relationship. These studies demonstrate the importance of considering pre-performance psychophysiological states when examining the influence of competitive pressure on motor performance.

Keywords: Demand/resource evaluations; emotions; conscious processing; quiet eye; kinematics; muscle activity

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Athletes commonly experience stress prior to, and during, pressurized competition. However, they often respond to this stress differently. One theoretical framework that offers a potential explanation for individual differences in stress response, but has received scarce research attention in sport, is the biopsychosocial model (BPSM) of challenge and threat (Blascovich, 2008). The present research examined the predictions of this model in both real competition and a laboratory-based task in order to aid our understanding of performance variability under competitive pressure.

Challenge and threat states

The BPSM (Blascovich, 2008), a model central to the theory of challenge and threat states in athletes (TCTSA; Jones, Meijen, McCarthy, & Sheffield, 2009), suggests that how individuals respond in a motivated performance situation (e.g., exam, speech, sport competition) is determined by their evaluations of situational demands and personal coping resources. Importantly, these evaluations can be conscious, unconscious (i.e., automatic), or both, and are only formed when an individual is actively engaged in the situation (evidenced by increases in heart rate and decreases in cardiac pre-ejection period; Seery, 2011). When personal coping resources are evaluated as sufficient to meet or exceed situational demands, a challenge state occurs. Conversely, when personal coping resources are evaluated as insufficient to meet situational demands, a threat state ensues (Seery, 2011). Research employing self-report measures has offered support for these divergent demand/resource evaluations (e.g., Tomaka, Blascovich, Kibler, & Ernst, 1997). Despite their discrete labels, challenge and threat are not considered dichotomous states but instead, as two anchors of a single bipolar continuum. Thus, research has often examined relative differences in challenge and threat (i.e., greater vs. lesser challenge or threat) rather than absolute differences (Seery, 2011).

The demand/resource evaluation process is said to trigger distinct neuroendocrine and cardiovascular responses, allowing challenge and threat states to be indexed objectively as well as subjectively (Blascovich, 2008; Seery, 2011). Elevated sympathetic-adrenomedullary activation is hypothesized to occur during both challenge and threat states. This activation causes the release of catecholamines (epinephrine and norepinephrine) and subsequently increased blood flow to the brain and muscles due to higher cardiac activity and vasodilation of blood vessels. Importantly, a threat state is also predicted to result in elevated pituitary-adrenocortical activation. This activation prompts cortisol to be released and a dampening of the sympathetic-adrenomedullary system, causing decreased blood flow due to reduced cardiac activity and diminished vasodilation (or even vasoconstriction). Consequently, compared to a threat state, a challenge state is associated with a more efficient cardiovascular response characterized by relatively higher cardiac output and lower total peripheral resistance (Seery, 2011). These cardiovascular indices have been well validated in the literature (see Blascovich, 2008 for a review).

According to the BPSM (Blascovich, 2008) and TCTSA (Jones et al., 2009), a challenge state should lead to better performance than a threat state. A number of empirical and predictive studies have supported this assumption (Mendes, Blascovich, Hunter, Lickel, & Jost, 2007; Seery, Weisbuch, Hetenyi, & Blascovich, 2010; Turner, Jones, Sheffield, & Cross, 2012). For example, Blascovich and colleagues found that exhibiting a challenge state in response to a sport-relevant speech task was associated with superior real-world performance, four to six months later during the competitive season (Blascovich, Seery, Mugridge, Norris, & Weisbuch, 2004). However, to date, no research has examined whether challenge and threat states (or underlying demand/resource evaluations), assessed immediately before a real pressurized competition, are associated with varying levels of performance. Furthermore, despite a recent study demonstrating that a challenge state directly results in better performance than a threat state during a novel motor task (Moore, Vine, Wilson, & Freeman, 2012), no research has examined the immediate impact of these states on the motor performance of experienced individuals. The present research was designed to shed light on these issues.

Possible underlying mechanisms

Several underlying mechanisms have been proposed to explain how challenge and threat states influence performance including those related to emotions, attention, and physical functioning (Blascovich et al., 2004; Jones et al., 2009). Firstly, the emotional response emanating from a challenge state is said to be more favourable than the response arising from a threat state. Specifically, relative to a threat state, a challenge state is assumed to result in more positive and less negative emotions, as well as more facilitative interpretations of emotions for performance (Jones et al., 2009). Recent research has supported this, demonstrating that a challenge state is associated with less cognitive and somatic anxiety, and a more positive interpretation of anxiety symptoms (Williams, Cumming, & Balanos, 2010). Positive emotions and facilitative interpretations of emotions are generally associated with successful performance, whilst negative emotions and debilitative interpretations are typically related to unsuccessful performance (Nicholls, Polman, & Levy, 2012; Thomas, Maynard, & Hanton, 2007). Thus, a challenge state might produce superior performance by stimulating more beneficial emotional responses.

Secondly, challenge and threat states are proposed to have divergent effects upon attention, with more effective attention accompanying the former. Specifically, attention is said to be focused on task-relevant cues during a challenge state, but towards task-irrelevant cues, or controlling one's actions, in a threat state (Blascovich et al., 2004; Jones et al., 2009). Research has shown that under pressure, focusing attention inwardly to consciously control the execution of autonomous motor skills is ineffective and can be detrimental to performance (Masters & Maxwell, 2008). Furthermore, research employing eye-tracking technology has demonstrated that when performing aiming skills under pressure, efficient attention is characterized by longer quiet eye durations (Vine, Moore, & Wilson, 2012). When lengthened, the quiet eye - defined as the final fixation towards a relevant target before movement initiation (Vickers, 2007) - is proposed to benefit pressurized performance by extending a critical period of information processing during which the motor response is selected, fine-tuned, and programmed (Vine et al., 2012). Therefore, a challenge state might result in better performance by encouraging more effective attention.

Thirdly, the behaviours and movements accompanying challenge and threat states are said to differ (Blascovich, 2008; Jones et al., 2009). Several studies have supported this prediction (O'Connor et al., 2010; Weisbuch, Seery, Ambady, & Blascovich, 2009). For instance, Mendes et al. (2007) found that, compared to a threat state, a challenge state resulted in more effective movements during an interaction task, including less freezing, avoidance posture, and more smiling. Thus, a challenge state might lead to superior performance by promoting movement patterns that are more likely to result in successful task completion. Finally, it is assumed that a challenge state may be associated with less muscular tension than a threat state (Wright & Kirby, 2003). To date, little research has examined this assumption. Given that successful performance has been linked with lower muscular activation (Lay, Sparrow, Hughes, & O'Dwyer, 2002), a challenge state could cause better performance by encouraging lower activation of task-relevant muscles.

A recent study by Moore et al. (2012) investigated the aforementioned mechanisms among a novice sample performing a golf putting task. Results indicated that a challenge state was associated with less somatic anxiety, more favourable interpretations of cognitive and somatic anxiety, longer quiet eye durations, more effective putting kinematics, and lower muscle activity. Mediation analyses revealed that only putting kinematic variables mediated the relationship between experimental group and performance. Thus, challenge and threat states mainly influenced novel motor task performance via kinematic mechanisms, impacting on the quality of task-related movements. To the author's knowledge, no studies have examined whether the underlying mechanisms highlighted by Moore and colleagues for novices might also explain the effects of challenge and threat states on experienced performers.

The present research

Drawing on the research outlined above, the aim of the present research was to investigate the immediate effect of challenge and threat states on the performance of experienced golfers during a real golf competition and a laboratory-based golf putting task. Specifically, the aim of study 1 was to examine the relationship between pre-competition challenge and threat states (assessed via demand/resource evaluations) and competitive performance. We hypothesized that evaluating the competition as a challenge (i.e., resources match or exceed demands) would predict better performance compared to evaluating it as a threat (i.e., demands exceed resources). This relationship was then investigated in more detail in study 2 using a laboratory-based task, the controlled context allowing for a more powerful test of the potential processes underpinning performance. The aim of study 2 was to examine the immediate impact of challenge and threat states on the golf putting performance of experienced golfers and to identify the possible mechanisms through which these states operate (emotional, attentional, kinematic, and/or physiological). We predicted that, compared to the threat group, the challenge group would exhibit relatively higher cardiac output and lower total peripheral resistance. Additionally, we predicted that the challenge group would outperform the threat group during the golf putting task; report a more favourable emotional response (i.e., less cognitive and somatic anxiety, and more facilitative interpretations of anxiety symptoms); and display more effective attention (i.e., less conscious processing and longer quiet eye durations); putting kinematics (i.e., lower clubhead acceleration and jerk); and muscle activation (i.e., lower extensor carpi radialis activity). Finally, in order to examine the potential mechanisms through which challenge and threat states might influence performance, mediation analyses were performed (Hayes & Preacher, 2013). Given previous findings (Moore et al., 2012), we predicted that putting kinematic variables might be the key mediators of any between-group differences in performance.

Study 1

Method

Participants. One hundred and ninety-nine golfers (34 women, 165 men; Mean age = 36.26 years; *SD* = 16.07) with official golf handicaps (Mean = 9.15; *SD* = 8.13) agreed to participate. All participants were competing in club championship competitions at various golf clubs across the [redacted]. For these participants, these competitions are often the biggest of the golf season both in terms of the size of the field taking part and prize money available, and so they tend to provoke high levels of pressure. Prior to the competitions, each participant read an information sheet outlining the details of the study and provided written informed consent. An institutional ethics committee approved the study protocol before data collection began.

Measures.

Demand/resource evaluations. Demand and resource evaluations were measured using two items from the cognitive appraisal ratio (Tomaka, Blascovich, Kelsey, & Leitten, 1993). Importantly, this measure has been used frequently and has been shown to closely corroborate with cardiovascular indices of challenge and threat (e.g., Moore et al., 2012; Tomaka et al., 1997; Zanstra, Johnston, & Rasbash, 2010). Competition demands were assessed by asking "How demanding do you expect the upcoming competition to be?" whilst personal coping resources were measured by asking "How able are you to cope with the demands of the upcoming competition?". Both items were rated on a 6-point Likert scale anchored between *not at all (= 1)* and *extremely (= 6)*. Previous research has typically calculated a ratio score by dividing evaluated demands by resources (e.g., Feinberg & Aiello, 2010). However, such a ratio is highly non-linear, and as such is inconsistent with the notion that challenge and threat states are two anchors of a single bipolar continuum (Seery, 2011). Thus, instead, a demand resource evaluation score was calculated by subtracting demands from resources (range: -5 to +5), with a more positive score reflecting a challenge state and a more negative score reflecting a threat state (see Tomaka et al., 1993).

Performance. An objective measure of competitive golf performance was assessed. Given that participants had different handicaps and competed in various competitions, on different courses, on different days, and with divergent weather conditions, a standardized measure was created (termed golf performance index). This measure was calculated by subtracting the competition standard scratch (difficulty rating of the competition[1]) and each participant's handicap from the number of shots taken on the eighteen competition holes (see Freeman & Rees, 2009 for more details). A lower index score indicated better performance.

Procedure. Firstly, upon arrival at the golf club, participants signed in for the competition and were approached about the study. Those participants who volunteered to take part then read the information sheet and provided written informed consent. Next, prior to their tee-off time (approximately 5-10 minutes), participants provided demographic information and completed the demand resource evaluation score in relation to the upcoming competition. After the competition, participants were thanked and debriefed about the aims of the study. The performance data was collected from the club secretary of each golf club two days after each competition.

Results and Discussion

One bivariate regression analysis was conducted to examine if participants pre-competition demand/resource evaluations (Mean demand resource evaluation score = 0.17; *SD* = 1.46) predicted a significant amount of variance in competitive golf performance (Mean golf performance index = 4.98; *SD* = 5.20). All assumptions relating to normality, homoscedasticity, linearity, normally distributed errors and independent errors were met. This analysis revealed that demand/resource evaluations made immediately prior to the competition accounted for a significant proportion of variance in golf performance index ($R^2 = .09$, $\beta = -.31$, $p < .001$). As hypothesized, these results suggest that golfers who evaluated the competition as more of a challenge (i.e., personal coping resources match or exceed competition demands), shot lower scores and outperformed those golfers who evaluated the competition as more of a threat (i.e., competition demands exceed personal coping resources).

The present study is the first to demonstrate that demand/resource evaluations (underpinning challenge and threat states) made immediately prior to a real-world pressurized competition can significantly predict competitive performance. The findings therefore extend previous research that has examined the distal effects (i.e., four to six months) of challenge and threat states on the real-world competitive performance of experienced individuals (e.g., Blascovich et al., 2004). Despite the encouraging findings, the present study is not without its limitations. Firstly, fluctuations in demand/resource evaluations throughout the competition were not assessed (e.g., hole to hole). Given the dynamic and complex nature of demand/resource evaluations, future research is encouraged to examine how these evaluations alter over time and the influence of re-evaluation on competitive performance and vice versa (see Quigley, Feldman Barrett, & Weinstein, 2002).

Secondly, by completing the self-report measure participants may have become aware that they had sufficient or insufficient resources to cope with the demands of the competition. This self-awareness may have altered participants' emotional responses and performance (Seery et al., 2010). Future research is therefore encouraged to employ objective measures to reduce the impact of self-awareness. Finally, although the present study had high ecological validity, this was at the expense of internal control. Thus, other uncontrolled variables may have influenced the relationship between pre-competition demand/resource evaluations and competitive performance. A laboratory-based protocol in which participants are experimentally manipulated into challenge and threat states would not only offer greater internal control, but would also enable stronger causal claims regarding the precise relationship between challenge and threat states and performance. The aim of study 2 was to address this limitation and examine the immediate effects of challenge and threat states on the golf putting performance of experienced golfers. Furthermore, the potential mechanisms through which challenge and threat states impact performance were also investigated.

Study 2

Method

Participants. Sixty golfers (4 women, 56 men; Mean age = 22.93 years; *SD* = 6.08) with official golf handicaps (mean handicap = 10.02; *SD* = 9.56) were recruited and tested individually. To be eligible to participate, golfers had to be right-handed, have normal or corrected vision, be non-smokers, free of illness or infection, and have no known family history of cardiovascular or respiratory disease. Furthermore, participants must not have performed vigorous exercise or ingested alcohol in the last 24 hours, and must not have consumed food and/or caffeine in the last hour. The study protocol was approved by the institutional ethics committee and written informed consent was obtained from each participant once they had read an information sheet outlining the details of the study.

Self-report measures.

Demand/resource evaluations. Demand and resource evaluations were assessed in the same way as in study 1. Only the wording of the two items comprising the demand resource evaluation score differed (i.e., "How demanding do you expect the golf putting task to be?", and, "How able are you to cope with the demands of the golf putting task?").

Cognitive and somatic state anxiety. The immediate anxiety measurement scale (Thomas, Hanton, & Jones, 2002) was used to measure participants' intensity and directional interpretations of anxiety symptoms. After reading definitions of cognitive and somatic anxiety, participants completed four items designed to assess the intensity (e.g., "To what extent are you experiencing cognitive anxiety right now?") and direction (e.g., "What effect do you think this cognitive anxiety will have on your upcoming performance on the task?") of each construct. All items were rated on a 7-point Likert scale anchored between *not at all (= 1)* and *extremely (= 7)* for intensity, and *very negative (= -3)* and *very positive (= +3)* for direction.

Conscious processing. A version of the conscious motor processing subscale of the Movement Specific Reinvestment Scale (MSRS; Orrell, Masters, & Eves, 2009) adapted for putting movements was used to assess conscious processing (see Cooke, Kavussanu, McIntyre, Boardley, & Ring, 2011). Participants were asked to indicate how they felt while putting in relation to six items, for example, ''I thought about my stroke'' and ''I tried to figure out why I missed putts''. Each item was rated on a 5-point Likert scale anchored between *never (= 1)* and *always (= 5)*.

Performance measures. Task performance was assessed in terms of both the percentage of putts successfully holed and the average distance the ball finished from the hole in cm (termed performance error). When a putt was successfully holed, zero was recorded and used in the calculation of performance error (as Moore et al., 2012; Moore, Vine, Freeman, & Wilson, 2013).

Quiet eye duration. An Applied Science Laboratories (ASL; Bedford, MA, USA) Mobile Eye Tracker was used to measure gaze (see Moore et al., 2012 for a detailed description of how gaze is recorded using this device). The quiet eye duration was operationally defined as the final fixation towards the ball prior to the initiation of the backswing (Vickers, 2007). Quiet eye onset occurred before the backswing and quiet eye offset occurred when the gaze deviated off the fixated object by 1° or more, for greater than 100 ms (Vickers, 2007). A fixation was defined as a gaze maintained on an object within 1° of visual angle for a minimum of 100 ms (Vickers, 2007).

Quiet Eye Solutions software (www.QuietEyeSolutions.com) was employed to analyse each putt frame-by-frame. Unfortunately, due to poor calibration, gaze data for 12 participants (challenge = 6, threat = 6) could not be analysed. Thus, a total of 348 putts were analysed. Importantly, the researcher was blind to the group each participant was in when analysing the data. A second analyst, also blind to group allocation, scored 10% of the quiet eye duration data and inter-rater reliability was assessed using the interobserver agreement method (Thomas & Nelson, 2001). This method estimates reliability using a formula that divides the number of commonly coded quiet eye durations (i.e., within 33.33 ms) by the sum of the commonly coded quiet eye durations and quiet eye durations coded differently. This analysis revealed a level of agreement at 83%.

Cardiovascular measures. Heart rate and cardiac output were estimated using a non-invasive impedance cardiograph device (Physioflow, PF05L1, Manatec Biomedical, Paris, France). Following procedures described by Moore et al. (2012), participants were fitted with the Physioflow device, which was then calibrated. Heart rate and cardiac output were estimated continuously during baseline (5 minutes) and post-manipulation (1 minute) time periods. Participants remained seated, still, and quiet throughout both time periods which were separated by approximately 90 seconds. Reactivity, or the difference between the final minute of baseline and the minute post-manipulation, was examined for all cardiovascular variables.

Although heart rate and cardiac pre-ejection period are both considered markers of task engagement (with greater increases in heart rate and decreases in cardiac pre-ejection period reflecting greater task engagement; Seery, 2011), only heart rate was used in the present study as the Physioflow does not allow cardiac pre-ejection period to be estimated. Cardiac output and total peripheral resistance are cardiovascular indices that differentiate challenge and threat states; with a challenge state characterized by higher cardiac output and lower total peripheral resistance (Seery, 2011). While cardiac output was 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 Dooren, 1990). Mean arterial pressure was calculated using the formula: [(2 x diastolic blood pressure) + systolic blood pressure / 3] (Cywinski, 1980).

Putting kinematics. Putting kinematic data was recorded using a tri-axial accelerometer (LIS3L06AL, ST Microelectronics, Geneva, Switzerland) and bespoke buffer amplifier (with a frequency response of DC to 15 Hz) mounted to the rear of the clubhead. A microphone (B5 Condenser, Behringer, Germany) connected to a mixing desk (Eurorack UB802, Behringer, Germany) detected the putter-ball contact on each trial. Signals were digitized at 2500 Hz. A computer program determined clubhead kinematics for each putt from initiation of the foreswing until the putter contacted the ball. Average acceleration of the clubhead in three axes (X = lateral, Y = vertical, and Z = back-and-forth) was calculated and enabled the assessment of clubhead orientation, clubhead height, and impact velocity, respectively. Furthermore, peak acceleration and root mean square jerk were also calculated for the Z-axis as the main axis involved in golf putting. The values from all trials were averaged to provide a test mean value for each kinematic variable (as Cooke, Kavussanu, McIntyre, & Ring, 2010; Moore et al., 2012).

Muscle activity. Electromyographic activity of the extensor carpi radialis muscle of the left arm was recorded using single differential surface electrodes (DE 2.1, Delsys) and an amplifier (Bagnoli-4, Delsys) with a ground electrode on the collar bone. This muscle was the focus of the present study as previous research has shown it to be the most influential in the golf putting stroke (Cooke et al., 2010). Electromyographic signals were amplified, filtered (20–450 Hz), and digitized (2500 Hz). Furthermore, the signal for each trial was rectified, and the mean amplitudes (microvolts) were calculated by averaging the activity over four consecutive periods (pre-movement initiation, backswing, foreswing, and post-contact). The duration of these periods were calculated from the Z-axis acceleration profile. The backswing lasted from movement initiation until the top of the backswing; the duration of the pre-movement initiation was the same as the duration of the backswing. The foreswing lasted from the top of the backswing until the putter hit the ball; the duration of the post-contact was the same as the duration of the foreswing. The trial values were averaged to provide a mean value for each electromyographic variable (as Moore et al., 2012).

Procedure. Firstly, after providing demographic information (age, handicap, experience, and rounds per week), the ASL Mobile eye-tracker and physiological recording equipment were fitted. Subsequently, 5 minutes of baseline cardiovascular data was recorded.

Next, participants received their respective manipulation (challenge or threat; see manipulation section). Cardiovascular data was then recorded for a 1 minute period. Participants remained seated, still, and quiet throughout this process. Afterward participants completed the demand resource evaluation score and immediate anxiety measurement scale. Following this, participants completed the task which consisted of six straight putts from three, 2.44 m locations to a half-size hole (diameter = 5.4 cm) on an artificial putting green (length = 6 m, width = 2.5 m; Stimpmeter reading = 3.28 m). A half-size hole was used to aid the effectiveness of the threat manipulation instructions (e.g., help ensure that participants believed that the task was difficult). All participants used the same golf putter (Sedona 2, Ping, Phoenix, AZ) and regular-size (diameter = 4.27 cm) white golf balls. Performance, gaze behaviour, putting kinematic, and muscle activity data were continuously recorded throughout all putts. Finally, participants completed the conscious processing measure, had all equipment removed, and were thanked and debriefed about the aims of the study.

Challenge and threat manipulations. Participants were randomly assigned to the two experimental groups using a random number generator (www.random.org) until an equal number of participants were in each group (Challenge *n* = 30; Threat *n* = 30). Instructional sets adapted from previous research were delivered verbally by the experimenter in order to manipulate participants into either a challenge or threat state (e.g., Feinberg & Aiello, 2010; Moore et al., 2012). To encourage task engagement, the instructions given to both groups emphasized the importance of the task; that their score would be compared against others taking part (published leaderboard); that the task was going to be objectively evaluated (digital video camera); that participants who performed poorly would be interviewed; and that participants who performed well would receive a financial reward (top 5 performers awarded cash prizes of £50, £25, £20, £15, and £10, respectively[2]). The challenge instructions encouraged participants to perceive the task as a challenge to be met and overcome, to think of themselves as someone capable of meeting that challenge, and highlighted that previous participants had performed well on the task. In contrast, the threat instructions focused on the task's high degree of difficulty and emphasized that previous participants had struggled to perform well on the task. Thus, the instructions aimed to promote challenge and threat states by influencing both evaluations of task demands and personal coping resources (instructions available from the lead author upon request).

Statistical analysis. Outlier analyses were performed prior to the main statistical analyses to ensure data was normally distributed. Consistent with previous research (Turner et al., 2012), data with z-scores greater than two were excluded from further analyses. Additionally, due to equipment problems, the cardiovascular data from one participant could not be recorded. A dependent *t*-test on the heart rate reactivity data was used to assess task engagement and establish that in the sample as a whole, heart rate increased significantly from baseline (i.e., heart rate reactivity greater than zero; as Seery, Weisbuch, & Blascovich, 2009). In order to differentiate challenge and threat states an index was created by converting each participant's cardiac output and total peripheral resistance residualised change scores into z-scores and summing them. Residualised change scores were calculated in order to control for baseline values. Cardiac output was assigned a weight of +1 and total peripheral resistance a weight of -1, such that a larger value corresponded with greater challenge (as Seery et al., 2009). To compare the groups, an independent *t*-test was conducted on the challenge and threat index data.

A series of independent *t*-tests were conducted on the demographic, self-report, performance, gaze, putting kinematic, and muscle activity variables to examine differences between the groups. All data were normally distributed as skewness and kurtosis z-scores did not exceed 1.96. For all *t*-tests the degrees of freedom, *t* statistic, and probability values were corrected for homogeneity of variance assumption violations using the Levene's test for equality of variances. Effect sizes were calculated using Cohen's *d*. Finally, to determine if significant differences in any of the process variables mediated the relationship between experimental group and performance, mediation analyses were conducted using the MEDIATE SPSS custom dialog (retrieved from http://www.afhayes.com) developed by Hayes and Preacher (2013). 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. Indeed, it is an inferential test of the indirect effect which is central to modern approaches to mediation and is thus the primary focus of our analyses (Hayes & Preacher, 2013).

Results

Demographics. There was no significant differences between the groups in terms of age, $t(58) = 1.37$, $p = .176$, $d = 0.36$, handicap, $t(58) = 0.04$, $p = .968$, $d = 0.01$, experience, $t(58) = 1.50$, $p = .140$, $d = 0.39$, or rounds per week, $t(58) = 0.03$, $p = .978$, $d = 0.01$. Thus, the randomization process was effective and the groups were equated prior to receiving the manipulation instructions (see Table 1).

Manipulation checks. In the sample as a whole, heart rate increased significantly from baseline by an average of 5.25 beats per minute ($SD = 4.97$), $t(58) = 8.04$, $p < .001$, $d = 2.11$, confirming task engagement and allowing the examination of challenge and threat states[3,4]. Compared to the threat group, the challenge group exhibited a significantly larger challenge and threat index value, $t(55) = 2.11$, $p = .040$, $d = 0.57$[5]. Furthermore, the challenge group reported a significantly higher demand resource evaluation score than the threat group, $t(58) = 5.42$, $p < .001$, $d = 1.42$ (see Table 1).

Performance. In contrast to the threat group, the challenge group holed a significantly higher percentage of putts, $t(58) = 2.41$, $p = .019$, $d = 0.63$. Moreover, the challenge group achieved a significantly lower performance error than the threat group, $t(56) = 2.61$, $p = .012$, $d = 0.70$[6] (see Table 1).

Cognitive and somatic anxiety. The challenge group reported experiencing significantly lower levels of cognitive, $t(49.80) = 4.89$, $p < .001$, $d = 1.39$, and somatic, $t(56) = 2.69$, $p = .009$, $d = 0.72$[7], anxiety than the threat group. Furthermore, compared to the threat group, the challenge group interpreted the cognitive, $t(58) = 2.29$, $p = .026$, $d = 0.60$, and somatic, $t(58) = 2.83$, $p = .006$, $d = 0.74$, anxiety they experienced as significantly more facilitative for their performance (see Table 1).

Conscious processing. The challenge group reported significantly less conscious processing than the threat group, $t(58) = 3.77$, $p < .001$, $d = 0.99$ (see Table 1).

Quiet eye duration. The challenge group displayed significantly longer quiet eye durations than the threat group, $t(46) = 4.72$, $p < .001$, $d = 1.39$ (see Table 1).

Putting kinematics. There was no significant difference between the groups in terms of X-axis (lateral) acceleration, $t(58) = 1.10$, $p = .277$, $d = 0.29$; Y-axis (vertical) acceleration, $t(58) = 1.49$, $p = .143$, $d = 0.39$; Z-axis (back-and-forth) acceleration, $t(57) = 1.51$, $p = .138$, $d = 0.40$[8]; peak acceleration, $t(55) = 0.02$, $p = .983$, $d = 0.01$[9]; or root mean square jerk, $t(58) = 1.09$, $p = .283$, $d = 0.29$ (see Table 1).

Muscle activity. There was no significant difference between the groups in terms of muscle activity during pre-initiation, $t(48.74) = 0.61$, $p = .543$, $d = 0.17$; backswing, $t(55) = 0.19$, $p = .853$, $d = 0.05$[10]; foreswing, $t(56) = 0.54$, $p = .594$, $d = 0.14$; or post-contact, $t(56) = 0.60$, $p = .549$, $d = 0.16$[11] (see Table 1).

Mediation analyses. To test if the relationship between group and performance was mediated by any of the process variables, experimental group (coded: challenge = 1, threat =

0) was entered as the independent variable, either percentage of putts holed or performance error was entered as the dependent variable, and a number of potential mediators were entered separately. Based on a 10,000 sampling rate, the results from bootstrapping revealed no significant indirect effects for any of the process variables with either percentage of putts holed or performance error entered as the dependent variable. This was because the 95% confidence intervals for all mediation analyses contained zero (see Tables 2 and 3). Thus, none of the process variables mediated the relationship between experimental group and performance.

Discussion

Challenge and threat states were successfully manipulated via task instructions (as Moore et al., 2012; Tomaka et al., 1997). Specifically, the challenge group reported a positive mean demand resource evaluation score, indicating that this group evaluated that they had sufficient resources to cope with the demands of the task. In contrast, the threat group reported a negative mean demand resource evaluation score, indicating that this group evaluated that they had insufficient resources to cope with task demands. In line with the predictions of the BPSM (Blascovich, 2008) and TCTSA (Jones et al., 2009), these divergent demand/resource evaluations led to different cardiovascular responses. Although the whole sample showed increases in heart rate reflecting task engagement (a pre-requisite of challenge and threat states; Seery, 2011), the challenge group displayed a larger index value than the threat group. Thus, the challenge group exhibited a cardiovascular response consisting of relatively higher cardiac output and lower total peripheral resistance compared to the threat group (Seery, 2011).

As predicted by the BPSM (Blascovich, 2008) and TCTSA (Jones et al., 2009), the challenge group outperformed the threat group in the golf putting task, successfully holing a higher percentage of putts and achieving a lower performance error. However, it should be noted that the percentage of putts successfully holed was low for both groups, reflecting the high degree of difficulty of the task (i.e., half-size hole). Nonetheless, these results equate to medium to large effect sizes and are congruent with previous research demonstrating that a challenge state typically facilitates performance whilst a threat state generally hinders performance (Blascovich et al., 2004; Mendes et al., 2007; Seery et al., 2010; Turner et al., 2012). For example, Moore et al. (2012) found that participants who exhibited a challenge state immediately prior to a novel golf putting task performed better than participants who displayed a threat state. The present study extends this research and is the first to demonstrate that challenge and threat states can have an immediate and direct effect (i.e., ~ 2 minutes post-manipulation) on the motor performance of experienced individuals, with a challenge state resulting in superior performance compared to a threat state.

As hypothesized, the emotional states emanating from challenge and threat states differed. Congruent with previous research (e.g., Moore et al., 2012; Williams et al., 2010), the challenge group reported experiencing less cognitive and somatic anxiety than the threat group. Furthermore, the challenge group interpreted the anxiety they experienced as facilitative for their performance, whilst the threat group interpreted the anxiety they felt as debilitative for their performance. However, mediation analyses revealed that none of the emotional variables mediated the effect of experimental group on either performance measure (percentage of putts holed or performance error). Thus, although challenge and threat states led to different emotional responses, these differences did not explain why the challenge group performed better than the threat group. This finding is consistent with those of Moore et al. (2012) who also found no evidence of underlying emotional mechanisms.

Challenge and threat states had different effects on attention. As predicted, the challenge group reported less conscious processing than the threat group. This suggests that the challenge group directed less attention inward, in an attempt to consciously control the mechanics of skill execution in a step-by-step manner. Such ‘reinvestment’ has been shown to have a detrimental effect on the performance of individuals performing automatized skills under pressure (Masters & Maxwell, 2008). Additionally, the challenge group displayed longer quiet eye durations than the threat group. Longer quiet eye durations accompany optimal performance under pressure and are proposed to benefit pressurized performance by extending a critical period of time during which the motor response is selected, fine-tuned, and programmed (Vine et al., 2012). Although challenge and threat states influenced attention differently, these differences failed to explain the performance differences between the groups. Mediation analyses revealed that neither attentional measure mediated the group-performance relationship.

Contrary to predictions, there were no significant differences between the groups in terms of putting kinematics or extensor carpi radialis activation. These results contradict previous research demonstrating that a challenge state is associated with more effective task-related movements (i.e., lower clubhead acceleration and jerk) and lower activation of task-relevant muscles compared to a threat state (Moore et al., 2012). These unexpected findings may be explained by the different samples studied. Whilst Moore and colleagues investigated a sample of novice golfers, the present study examined a sample of experienced golfers. Indeed, recent research has identified that the control of the putting stroke and muscle activity patterns may have less influence on the putting proficiency of experienced golfers compared to other factors such as the ability to accurately judge the speed of the putting green (Cooke et al., 2011; Karlsen & Nilsson, 2008; Karlsen, Smith, & Nilsson, 2008).

Despite the interesting findings, the limitations inherent in the present study must be acknowledged. Firstly, a between-subjects design was employed and baseline performance was not assessed (unlike Turner et al., 2012). However, it should be noted that the amount of exposure to a task can dampen cardiovascular responses and that prior task performance can influence subsequent demand and resource evaluations (Kelsey et al., 1999; Quigley et al., 2002). Thus, individuals who previously performed poorly on a task may be more likely to evaluate the task as a threat in the future compared to individuals who performed well on the task. Additionally, the effects of challenge and threat states were only investigated over six trials. Although this may cause some concern, demand and resource evaluations are said to be dynamic and fluctuate during a task as new information becomes available (Blascovich, 2008; Jones et al., 2009; Quigley et al., 2002). Therefore, although individuals may evaluate a task as a threat at first, this might alter after one or two trials, causing individuals to evaluate the task as less threatening or even challenging, and vice versa. Performance may be influenced by such re-evaluation and so few trials were employed to decrease the impact of re-evaluation. However, the complex and reciprocal relationship between demand/resource evaluations and performance would be an interesting avenue for future research.

General discussion

A challenge state has been associated with superior distant real-world performance compared to a threat state (Blascovich et al., 2004). Furthermore, challenge and threat states have been shown to have direct effects on the performance of a novel motor task, with a challenge state resulting in better performance (Moore et al., 2012). However, to date, no research has examined the immediate impact of challenge and threat states (assessed via subjective or objective measures) on the motor performance of experienced individuals. The present research aimed to do this in both a real golf competition (study 1) and a laboratory-based golf putting task (study 2). Moreover, the present research (study 2) aimed to examine multiple underlying processes through which challenge and threat states might influence performance.

Study 1 revealed that demand and resource evaluations (determining challenge and threat states) made immediately prior to a real pressurized competition can significantly impact upon competitive performance. Specifically, those golfers who evaluated the competition as a challenge performed better during the round than those who evaluated the competition as a threat. Study 2 demonstrated that challenge and threat states can have a direct effect on the motor performance of experienced individuals, with golfers in the challenge group outperforming golfers in the threat group. Furthermore, compared to the threat group, the challenge group reported experiencing less cognitive and somatic anxiety, more facilitative interpretations of anxiety, less conscious processing, and longer quiet eye durations. However, the groups did not differ in terms of any of the putting kinematic or muscle activity variables. Finally, mediation analyses revealed that none of the process variables mediated the relationship between experimental group and performance.

A number of possible explanations might explain the lack of mediation. Firstly, the cross-sectional nature of study 2 may have inhibited the exploration of potential underlying mechanisms. Indeed, authors have noted that modelling underlying processes over time using a longitudinal design may provide a more sensitive test of probable mechanisms (Uchino, Bowen, Carlisle, & Birmingham, 2012). Secondly, the measures employed in study 2 to assess the various mechanisms may not have been the most sensitive. For example, conscious processing was assessed via a self-report measure when an objective measure such as alpha2 T3-Fz neural co-activation may have offered a more direct examination of this attentional mechanism (see Zhu, Poolton, Wilson, Maxwell, & Masters, 2011). Similarly, the tri-axial accelerometer could not measure all potentially relevant kinematic variables (e.g., clubface angle at impact; Karlsen et al., 2008). Thus, whilst both groups executed the putting stroke similarly, the challenge group may have had the face of the clubhead more accurately aligned with the hole as the putter contacted the ball. Unfortunately, we can only speculate about this possible underlying process and it remains for future research to explore this and other potential explanations.

The findings of the present research have some important implications. From a theoretical perspective, the findings support the predictions of the BPSM (Blascovich, 2008) and TCTSA (Jones et al., 2009) and highlight both models as useful frameworks by which performance variability under pressure can be better understood. Importantly, the findings were robust across different research designs and contexts. Furthermore, from an applied perspective, the findings suggest that interventions aimed at helping athletes evaluate highly pressurized competition more adaptively, as a challenge rather than a threat, should not only encourage more favourable emotional and attentional responses, but should also facilitate stress-resilient performance (Fletcher & Sarkar, 2012). Moreover, such interventions may also have important health benefits given the links between repeated threat cardiovascular reactivity and a number of deleterious health outcomes (e.g., cellular aging; O'Donovan et al., 2012). Indeed, the findings of the present study and previous research suggest that such modifications could be made with an intervention as subtle and inexpensive as manipulating the way the task is framed (e.g., Feinberg & Aiello, 2010). Thus, coaches and sport psychologists should be aware of the impact their instructions can have on task performance and should aim to frame pressurized tasks in a manner consistent with challenge.

The limitations of the present research highlight some directions for future research. Firstly, the antecedents of challenge and threat states were not assessed in either study but could be examined in future research. Indeed, a range of factors have been proposed to influence the demand/resource evaluation process including psychological and physical danger, familiarity, uncertainty, required effort, skills, knowledge and abilities, and the availability of external support (Blascovich, 2008). Secondly, whilst the cardiovascular measures of challenge and threat states were recorded in study 2, the neuroendocrine responses predicted to drive changes in these measures were not (e.g., cortisol; see Seery, 2011). Thus, future research is encouraged to provide data on the neuroendocrine changes accompanying challenge and threat states to help elucidate how these states impact the cardiovascular system. Thirdly, a simplified model of the challenge/threat-performance relationship was examined in both studies. Furthermore, in study 1, consistent with the BPSM (Blascovich, 2008), challenge and threat states were examined as anchors of a bipolar continuum rather than dichotomous states. However, some theorists argue that challenge and threat are fluid dichotomous states and that individuals can experience both simultaneously (Lazarus & Folkman, 1984). Future research should therefore examine a more complex model in which the dynamic and precise nature of challenge and threat states is taken into consideration. Finally, previous research has only investigated the immediate impact of challenge and threat states on the motor performance of aiming tasks (e.g., Moore et al., 2012). Future research is therefore encouraged to explore their effects on the performance of a range of tasks including decision-making, interceptive, and team-based motor tasks.

To conclude, the results of the present research demonstrate that challenge and threat states (assessed via subjective and objective measures) can have an immediate effect on the motor performance of experienced individuals in both real pressurized competition and a laboratory-based task. In each setting, a challenge state was associated with superior competitive performance compared to a threat state. Furthermore, in a laboratory-based context, a challenge state was associated with more favourable emotional responses and attentional processes. Collectively, these results suggest that by using interventions that encourage individuals to evaluate that they possess the resources to cope with the demands of a pressurized competition, practitioners could develop future champs rather than chumps.

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Footnotes

1. Competition standard scratch is employed on the day of competition to quantify the influence of weather and course conditions on the scoring ability of the golfers and to make adjustments to their handicaps. This system is used in the United Kingdom and is equivalent to the slope rating system used in North America.
2. It should be noted that the cash prizes were given to the top 5 performing participants.
3. Heart rate reactivity data from 1 participant was identified as an outlier and excluded from all analyses.
4. Heart rate increased significantly from baseline for both the challenge group (*M* = 8.15 bpm, *SD* = 4.64), *t*(29) = 9.64, *p* < .001, *d* = 3.58, and the threat group (*M* = 2.13 bpm, *SD* = 3.10), *t*(27) = 3.64, *p* = .001, *d* =1.40.
5. Challenge and threat index data from 2 participants were deemed outliers and removed from all analyses.
6. Performance error data from 2 participants were identified as outliers and excluded from all analyses.
7. Somatic anxiety intensity data from 2 participants were deemed outliers and removed from all analyses.
8. Z-axis acceleration data from 1 participant was identified as an outlier and excluded from all analyses.
9. Peak acceleration data from 3 participants were deemed outliers and removed from all analyses.
10. Pre-initiation and backswing muscle activity data from 3 participants were identified as outliers and excluded from all analyses.
11. Backswing and post-contact muscle activity data from 2 participants were deemed outliers and removed from all analyses.

Table 1. Mean (*SD*) demographic, manipulation check, performance, cognitive and somatic anxiety, conscious processing, gaze, putting kinematic, and muscle activity data for challenge and threat groups.

	Challenge		Threat		Effect Size
	Mean	*SD*	Mean	*SD*	*d*
Age (years)	24.00	7.03	21.87	4.83	0.36
Handicap	9.97	10.13	10.07	9.13	0.01
Experience (years)	9.08	4.21	7.60	3.42	0.39
Rounds per week	2.02	1.31	2.03	1.25	0.01
Challenge and threat index	0.23	1.41	-0.63	1.64	0.57*
Demand resource evaluation score	1.50	1.20	-0.30	1.37	1.42*
Percentage of putts holed (%)	17.88	15.11	9.57	11.40	0.63*
Performance error (cm)	15.84	7.41	21.04	7.73	0.70*
Cognitive anxiety intensity	2.07	0.69	3.20	1.06	1.39*
Cognitive anxiety direction	0.40	0.93	-0.20	1.10	0.60*
Somatic anxiety intensity	1.97	0.76	2.50	0.75	0.72*
Somatic anxiety direction	0.17	0.91	-0.47	0.82	0.74*
Conscious processing	2.84	0.65	3.41	0.51	0.99*
Quiet eye duration (ms)	2148.22	496.27	1541.69	388.19	1.39*
X-axis acceleration ($m.s^{-2}$)	0.42	0.16	0.38	0.15	0.29
Y-axis acceleration ($m.s^{-2}$)	0.77	0.26	0.86	0.20	0.39
Z-axis acceleration ($m.s^{-2}$)	4.20	1.22	3.81	0.66	0.40
Peak acceleration ($m.s^{-2}$)	4.61	0.78	4.60	0.97	0.01
Root mean square jerk ($m.s^{-2}$)	4.22	1.17	3.94	0.77	0.29
Pre-initiation muscle activity (µV)	23.04	7.15	24.59	11.68	0.17
Backswing muscle activity (µV)	31.88	10.65	32.45	12.50	0.05
Foreswing muscle activity (µV)	38.28	15.58	36.01	16.54	0.14
Post-contact muscle activity (µV)	30.73	12.48	28.75	12.47	0.16

Note: significant difference between challenge and threat groups, * = $p < .05$

Table 2. Mediation results for all cognitive and somatic anxiety, conscious processing, and gaze variables with experimental group entered as the independent variable and percentage of putts holed entered as the dependent variable.

	Effect	*SE*	LL 95% CI	UL 95% CI
Cognitive anxiety intensity	-1.41	2.38	-6.40	2.92
Cognitive anxiety direction	0.61	1.13	-1.68	3.00
Somatic anxiety intensity	1.24	1.35	-1.25	4.14
Somatic anxiety direction	0.63	1.19	-1.55	3.26
Conscious processing	2.36	1.81	-1.03	6.25
Quiet eye duration	-0.88	2.55	-6.27	4.00

Note: LL = lower limit; CI = confidence interval; UL = upper limit, No indirect effects were significant

Table 3. Mediation results for all cognitive and somatic anxiety, conscious processing, and gaze variables with experimental group entered as the independent variable and performance error entered as the dependent variable.

	Effect	*SE*	LL 95% CI	UL 95% CI
Cognitive anxiety intensity	-0.90	1.12	-2.98	1.52
Cognitive anxiety direction	0.64	0.69	-0.64	2.17
Somatic anxiety intensity	-0.50	0.86	-2.43	1.05
Somatic anxiety direction	0.57	0.73	-0.97	2.03
Conscious processing	-1.60	1.01	-3.76	0.25
Quiet eye duration	-1.54	1.71	-5.35	1.46

Note: LL = lower limit; CI = confidence interval; UL = upper limit, No indirect effects were significant