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Abstract

This study assessed physiological (cardiovascular) and psychological (confidence, control, and approach focus) data in professional academy soccer players prior to performance in competitive matches. A challenge state is characterised by an increase in cardiac output (CO), and a decrease in total peripheral vascular resistance (TPR). Data were collected from 37 participants, with 19 of these providing data on two separate occasions. Performance was measured using coach and player self-ratings. Challenge reactivity was positively, and significantly, associated with performance. Participants who demonstrated blunted cardiovascular (CV) responses performed significantly worse than participants who displayed either challenge or threat reactivity. There was mixed consistency in CV reactivity for those participants whose data were collected on more than one occasion, suggesting that some participants responded differently across the competitive matches. The association between self-report data and CV responses was weak. This study supports previous research demonstrating that challenge reactivity is associated with superior performance.

Keywords: *theory of challenge and threat states in athletes, cognitive appraisal, emotion, soccer, stress*

Introduction

A motivated performance situation is a circumstance in which an individual must exert effort to achieve goals that are self-relevant and important (Seery, 2011). Athletes can approach motivated performance situations (e.g., competition) in either a challenge or a threat state (e.g., Blascovich, Seery, Mugridge, Norris, & Weisbuch, 2004; Turner, Jones, Sheffield, Slater, Barker, & Bell, 2013). A challenge state is regarded in a sporting context as adaptive, and threat state as a maladaptive (Jones, Meijen, McCarthy & Sheffield, 2009). The present study used professional soccer as a context to explore challenge and threat states prior to competition and their association with performance. Professional soccer is a suitable context as it has a number of stressors impacting on players, both on and off the field (e.g., Holt & Hogg, 2002; Jordet, Hartman, Visscher, & Lemmink, 2006; Gouttebarge, Frings-Dresen, Sluiter, 2015).

The biopsychosocial (BPS) model of challenge and threat (Blascovich & Mendes, 2000; Blascovich & Tomaka, 1996) draws on the cognitive appraisal theory of Lazarus and Folkman (1984) to describe how psychophysiological responses to motivated performance situations reflect either a helpful or unhelpful approach. Blascovich and colleagues also built on the concept of physiological toughness (Dienstbier, 1989) to outline how challenge and threat reactivity occurred in response to motivated performance situations (Blascovich & Mendes, 2000; Blascovich, & Tomaka, 1996; Blascovich et al., 2004; Tomaka, Blascovich, Kelsey & Leitten, 1993). This approach was specifically adapted to sport in the Theory of Challenge and Threat States in Athletes (TCTSA; Jones et al., 2009). A challenge state occurs when evaluated personal coping resources meet or exceed situational demands, whereas threat occurs when demands exceed resources (Blascovich, & Tomaka, 1996). These evaluations are purported to trigger the specific neuroendocrine and cardiovascular responses that are proposed to indicate a challenge or threat state. Demands comprise danger, uncertainty, and effort while in the TCTSA resource evaluations comprise three interrelated constructs (self-efficacy, perceptions of control, and achievement goals). Resource evaluations determine whether the individual perceives sufficient or insufficient resources to meet the demands of a situation and is a dynamic process which means cardiovascular responses can fluctuate when the individual is presented with new contextual information (e.g. Tomaka, Blascovich, Kibler, & Ernst, 1997).

According to the TCTSA, self-efficacy is an important part of the resource appraisal process because it supports the perception that an individual can cope with the demands of a situation. Perceived control refers to the beliefs an individual has about how much control is available in a situation. Challenge and threat states can be influenced by whether an individual perceives a situation as within or outside their personal control (Meijen, Jones, McCarthy, Sheffield, & Allen, 2013). The TCTSA purports that approach goals are related to a challenge state and avoidance goals to a threat state (drawing on the research undertaken on achievement goals; Adie, Duda, & Ntoumanis, 2008; McGregor & Elliot, 2002). Whilst research testing the BPS model and the TCTSA have found support for challenge and threat patterns of CV reactivity being associated with sport performance (e.g. Moore, Vine, Wilson, & Freeman, 2012; Moore, Wilson, Vine, Coussens, & Freeman, 2013; Turner, Jones, Sheffield, & Cross, 2012; Turner et al., 2013; Turner, Jones, Sheffield, Barker, & Coffee, 2014), there is mixed evidence to support the proposed relationships between the resource appraisals, CV indices of challenge and threat and emotions in the TCTSA (cf. Trotman, Williams, Quinton, & Veldhuijzen van Zanten, 2018; Turner et al., 2012; Turner et al., 2013). However, there is stronger evidence that using approaches designed to improve resource appraisals can have an impact on challenge states, such as imagery (Williams, Veldhuijzen van Zanten, Trotman, Quinton, & Ginty, 2017) or task instructions (Turner et al., 2014).

Challenge and threat states result from activation of the sympathetic nervous system (SNS). In a challenge state it is proposed that the sympathetic adrenomedullary system and the resultant catecholamine output (epinephrine and norepinephrine) increases cardiac performance and decreases vascular resistance. A threat state is also marked by increased activation of the sympathetic adrenomedullary system but also accompanied by increased pituitary adreno-cortical activity, and increased levels of cortisol which inhibits epinephrine and norepinephrine release (Blascovich & Tomaka, 1996; Dienstbier, 1989). Small, or no changes, in total peripheral resistance (TPR; sum of the resistance of all peripheral vasculature in the systemic circulation[dyn.s.cm-5]), and no change or a small increase in cardiac output (CO; litres of blood pumped from the heart per minute[l/min]), indicate a threat state, while a challenge state is inferred by a decrease in TPR and an increase from baseline in CO (Blascovich & Mendes, 2000).

The mechanisms behind the cardiovascular patterns of challenge and threat and the relative contribution of the sympathetic adrenomedullary, and pituitary adreno-cortical systems have been debated (see Blascovich, Mendes, Tomaka, Salomon, & Seery, 2003). More recent explanations have focused on the temporal aspects of the SNS response proposing that challenge states result from a quick SNS response which quickly habituates, whereas threat states have a slower rise in SNS activity which tends to stay elevated for a longer time (Epel et al., 2018). It is this response that is reflected in the differing patterns of challenge and threat cardiovascular reactivity. Because challenge and threat states reflect SNS activity increases in heart rate (HR; heart beats per minute[bpm]) is considered a pre-requisite as it reflects engagement with the situation (Blascovich, Mendes, Vanman, & Dickerson, 2011). However, there is a growing body of evidence that under stress some people demonstrate a blunted CV response (Phillips, Ginty, & Hughes, 2013) with little change in HR. A blunted CV response, has been defined as a CV 'response pattern that is comparatively lower than that which is seen during a typical state of homeostatic function during stress' (Phillips, et al., 2013, p.2). Therefore, no observable change HR may indicate a blunted response to stress and not necessarily a lack of task engagement. Indeed, according to Lovallo (2013), the most optimally healthy response to stress is a moderate reaction.

According to the TCTSA, challenge states facilitate cognitive and physical performance and typically comprise emotions that are positive, or perceived as positive, while threat states inhibit mental and physical performance and typically comprise emotions that are negative, or perceived as negative (Jones et al., 2009). Challenge states have been consistently associated with improved performance in a range of environments and activities. These include word search tasks (Mendes, Major, McCoy, & Blascovich, 2008), mental arithmetic tasks (Tomaka et al., 1997) and, pattern-recognition task and number-categorisation tasks (Blascovich, Mendes, Hunter, & Salomon, 1999). Similar relationships between CV reactivity and performance have also been demonstrated in sport settings such as baseball and softball over the course of a season (Blascovich et al., 2004), sports task in the laboratory, such as, golf putting (Moore et al., 2012) and netball (Turner et al., 2012). Challenge CV reactivity also predicted superior performance, compared with threat CV reactivity in a pressured batting test (manipulated performance situation) for male county and junior national cricketers (Turner et al., 2013). Two recent reviews have also found support for the predicted performance outcomes of challenge and threat states. In their meta-analysis using pooled effect sizes covering 19 studies (total N=1045), Behnke and Kaczmarek (2018) found the association between the level of performance and CV markers of challenge and threat was significant. Further, following a systematic review across 38 published studies Hase, O'Brien, Moore, and Freeman (2018) also found support for the performance benefits of a challenge state. However, both recent reviews cite limitations with challenge and threat research literature including the diversity of tested populations, and, an under reporting of weaker effects (Behnke et al., 2018) and a need for more longitudinal research (Hase et al. 2018).

The present study explores stress responses in professional academy soccer players, and applies a repeated measures design to explore CV reactivity to motivated performance settings. Thus the research extends the extant literature in two ways. First, it uses a sample of professional athletes whose careers depend on successful performance outcomes and investigates the relationship between pre-match cardiovascular reactivity and measures of psychological state with performance in the match. As such, it meets the call for research with more diverse populations (Behnke et al., 2018). It also extends current understanding by exploring the consistency of CV reactivity across matches, addressing the call for more longitudinal research (Hase et al., 2018). Previous research has explored how appraisals underlying CV reactivity have changed over time (Quigley, Feldman Barrett, & Weinstein, 2002; Sammy, Anstiss, Moore, Freeman, Wilson, & Vine, 2017), but to date no studies have explored whether CV reactivity to motivated performance settings is consistent within individuals. Exploring consistency in reactivity patterns gives an indication of how stress responses differ across different games in professional sport, and allows investigation into whether individuals have set responses to motivated performance situations, building on previous longitudinal challenge and threat research (e.g. Cumming, Turner, & Jones, 2017). There is clear evidence that challenge states predict superior performance compared to threat states in laboratory settings (e.g. Turner et al., 2013), using self-report measures (e.g. Moore et al., 2013), and over the course of a sporting season (e.g. Blascovich et al., 2004). However, no study has explored how challenge and threat states relate to performance in an actual, rather than staged, single sports performance using CV reactivity. Further, it is not yet known the extent to which challenge and threat responses remain consistent over different motivated performance situations.

Consequently, the aim of the study is to investigate the relationship between challenge and threat states and performance in professional academy soccer players and to explore the consistency of these states in participants using a repeated measures design. Based on the BPS, the TCTSA, and previous research (e.g. Blascovich et al, 2004; Seery, Holman, & Silver, 2010; Moore et al., 2012; Turner et al., 2012; Turner et al., 2013) it was hypothesised that CV reactivity indicating a challenge state would predict better performance in the match, compared with CV reactivity indicating a threat state. It was also hypothesised based on previous within-subjects research that CV responses would not be consistent across the two testing time points (Quigley et al., 2002). As self-report measures of the TCTSA antecedents do not consistently relate to challenge and threat reactivity (e.g., Meijen, et al., 2013; Turner et al., 2012; Turner et al., 2013), it was hypothesised that CV reactivity would not be associated with self-reported emotions, achievement goals, self-efficacy, and perceived control.

Methods

Participants

Participants (*N* = 37) were male, professional (all on full-time, paid contracts), soccer players in a Premier League Category 1 Academy for either the U18s or U21s team (*M* age = 17.95, *SD* = 1.31). Participants had an average of 10.3 years (*SD* = 2.57) playing experience and were all recruited by the first author who worked at the academy and made a verbal request for volunteers. Of the 37 participants, 18 completed the process once (single measure) and 19 completed the process twice (repeated-measures). The testing period covered a time span of 16 months. Prior to any data collection ethical approval was granted by the University, and informed consent was obtained from participants over the age of 18. For participants under the age of 18 informed consent was obtained from parents and assent from the players themselves. The testing period covered a time span of 16 months.

Measures

Cardiovascular reactivity

HR, CO and TPR, were measured using a Finometer Pro ® machine. This non-invasive device used a finger cuff placed on the middle finger and an arm cuff placed on the same-side upper arm of the participant.

Self-Report Measures

Emotions were assessed using the Sport Emotion Questionnaire (SEQ; Jones, Lane, Bray, Uphill, & Catlin, 2005). Participants indicated how they felt about the imminent soccer match on a 5-point Likert scale ranging from 0 (not at all) to 4 (extremely). The Achievement Goals Questionnaire (AGQ; Conroy, Elliot, & Hofer, 2003) measured mastery approach, mastery avoidance, performance approach, and performance avoidance goals on a 7-point Likert scale ranging from 1 (not at all true) to 7 (very true). Self-efficacy was measured using Coffee and Rees' (2008) self-efficacy questionnaire; eight questions focusing how demanding, effortful, uncertain and, how important doing well in the imminent soccer match was for participants on a 6-point Likert scale ranging from 1 (not at all true) to 6 (very true). Perceived control was assessed using the adapted Academic Control Scale (Perry, Hladkyj, Pekrun, & Pelletier, 2001), comprising eight statements relating to their perceived control regarding the upcoming match on a 5-point Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree). All measures were repeated for participants undertaking the second testing time point.

Performance Ratings

Players were asked to give a post-performance rating in response to the question: *If 100% represents you performing at your best, what percentage would you give yourself based on your performance in the match that you have just participated in?* The coach of the team was asked to provide a rating, to the following question: *If 100% represents the player performing at their best, what percentage would you give them based on their performance in the match they have just participated in?* Ratings were obtained from participants after both testing time points (for those who undertook the repeated measures).

Procedure

Data collection was undertaken on the day of a match in which the participants were expecting to play (confirmed to the researcher in advance of the match confidentially by the coach). Prior to commencing the data collection, the participants and coaches were provided with an information sheet detailing the purpose of the study and completed a consent form.

Participants reported earlier to the club's training ground facility than the rest of their team in order to go through the 30-minute testing process and, minimise any potential disruption to their normal pre-match routine between 3 and 2.5 hours before kick-off. Each participant was connected to the Finometer Pro ® cardiovascular recording equipment (in a private room). An acclimatisation period lasting 10 minutes, was undertaken in order to ensure the equipment was calibrated and recording data correctly. Following the acclimatisation period, the participant was encouraged to relax and, 5 minutes of baseline data (CO, HR and, TPR) was collected. The participant was then required to listen to the following set of audio instructions (using noise cancelling headphones) relating to the upcoming game, lasting 30 seconds:

"Today you will be playing in an important match.

As with all games at this level it will be demanding.

It is another important step in your journey towards becoming a first-team player.

As always the coach is interested in how you perform.

Take some time to prepare mentally for the game as you normally would."

Participants were then asked to think about performing in the upcoming game whilst further cardiovascular data (CO, HR and, TPR) was collected for 2 minutes. Following the cardiovascular data collection, participants were asked to complete self-report measures of self-efficacy, perceived control, achievement goals, and emotions in relation to the upcoming game. To explore whether they complied with the task participants completed a measure asking them whether they were able to think about the match, and whether they felt anything physically during the 2 minutes thinking time post-audio instructions (for both questions choosing from the options of yes, no, or partially).

Within 72 hours of the game finishing, both the player (completion time hours post-game; $M = 31$, $SD = 9.35$) and his head coach (completion time hours post-game; $M = 30$, $SD = 8.53$) completed (separately) the performance measure. Prior to commencing the data collection, the coaches were also provided with an information sheet detailing the purpose of the study, the procedures and confidentiality of data and participant identity and, completed a consent form before undertaking this process.

The methodology was repeated (within subjects-design) after a minimum of 3 months (for 19 of the participants). Following data collection each participant was debriefed about the study. The level of opponents were teams from the same competitive league.

On one occasion, CV data from a participant was potentially compromised due to the Finometer Pro ® cutting out several times during the data collection procedure. On another occasion a player was removed from the starting line-up following the testing procedure and therefore performance ratings could not be completed. On both occasions the data collected was removed from the final analysis.

Analytic Strategy

Before inferential analyses, we explored each individual participants' heart rate reactivity as a pre-requisite for challenge and threat states (c.f. Blascovich et al., 2011). Sixteen participants demonstrated a blunted HR response (no increase in HR from baseline) thus precluding challenge and threat CV assessment for these participants. Subsequently, main data analyses comprised six main steps. First, task compliance was assessed using the post-testing questions (all participants) relating to the ability to do the task as requested and any perceived physiological changes. Second HR reactivity was confirmed for the 21 participants (full sample minus the 16 participants who had a blunted HR response) via a paired samples t-test for the 21 participants. Third, for the 21 participants who demonstrated HR reactivity three separate hierarchical multiple linear regression analyses were conducted to explore the relationships between a challenge and threat (CT) index and the three performance indicators (player rating, coach rating, and player and coach rating combined). A single CT index was calculated by converting average CO and average TPR reactivity values into *z* scores and summing them for those participants that were reactors. Cardiac output was assigned a weight of +1 whereas TPR was assigned a weight of -1, so that larger values reflected greater challenge reactivity (e.g. Blascovich et al., 2004; Turner et al., 2013). In step 1, participant age and years of experience were entered for each participant (e.g., Turner et al., 2013), and in Step 2 the CT index was entered. Fourth, for all participants three separate between-subjects ANCOVAs, with age and years experience as covariates, with blunted responders (no increase in HR), challenge responders (positive score on CT Index), threat responders (negative score on CT Index) as the independent variable for player performance rating, coach performance rating and, player and coach performance rating combined were then undertaken. Fifth, for the 21 participants who demonstrated HR reactivity the Pearson's correlation analyses were used to examine the association between CV reactivity, self-reported psychological states, and performance ratings (player, coach and player and coach performance rating combined). Finally, the within-subjects changes in the CT index from time point 1 to time point 2 were assessed in all participants who had undertaken the data collection procedure twice using a paired-samples t-test. All multicollinearity, normality, and outlier checks met the assumptions necessary for all data analyses.

Results

Task Compliance

Participants indicated that they were able to engage in the task through the post-testing questions. In response to the question whether they were able to think about the match from the 56 testing time points (18 participants who completed the process once and 19 who completed the process twice) 46 responses were 'Yes', and 10 'Partially'. Of the 56 testing time points, on 44 occasions participants reported feeling some form of physiological change and on 12 occasions no changes.

HR Reactivity

A paired samples t-test of twenty-one participants who demonstrated an increase in heart rate confirmed there was a significant increase, $t\,(21) = 6.65$, $p < .001$, in HR from baseline ($M = 65.17$ bpm, $SD = 11.01$), to post-instructions ($M = 67.32$ bpm, $SD = 11.29$ bpm), which is an important prerequisite for challenge and threat CV analysis.

Challenge and threat index and performance

Based on the CT index the 21 participants who demonstrated an increase in heart rate were defined as either challenge (N = 10) or threat (N = 11) CV responders. Shapiro-Wilk tests were performed on the CT index showing that the data was normally distributed and demonstrating no significant outliers, (Non-significant $p > .05$). Three separate hierarchical multiple linear regression analyses were conducted to explore the relationships between the CT index and the three performance indicators (player rating, coach rating, and player and coach rating combined).

Player and coach performance ratings combined

The hierarchical multiple regression analysis revealed that in Step 1 (age and years' experience) a significant proportion of variance was not accounted for, $R^2 = .10$, $p = .39$. The addition of the CT index in Step 2 accounted for a significant proportion of variance, R^2 *Change* = .38, $p = .02$. Greater challenge reactivity was positively associated with greater performance scores ($\beta = .57$, $p = .02$).

Coach performance rating

In Step 1 a significant proportion of variance was not accounted for, $R^2 = .05$, $p = .66$. The addition of the CT index in Step 2 did not account for a significant proportion of variance, R^2 *Change* = .38, $p = .11$ ($\beta = .42$).

Player performance rating

In Step 1 a significant proportion of variance was not accounted for, $R^2 = .15$, $p = .26$. The addition of the CT index in Step 2 accounted for a significant proportion of variance, R^2 *Change* = .42, $p = .015$ ($\beta = .57$).

Performance differences by CV response

A between-subjects ANCOVA was undertaken to examine differences in player and coach combined performance ratings across the three CV response types; challenge, threat, and blunted responders, and mean scores and standard deviations are included in Table 2. There was a significant between-subjects effect, F (2, 31) = 3.99, p = .029, partial eta squared = .21. Pairwise comparisons demonstrated significant (p = .03) univariate main effects for challenge responders compared to blunted responders, demonstrating that challenged participants performed better than blunted responders. The analysis was repeated for separate player and coach performance ratings showing a significant between-subjects effect remained for player ratings, F (2, 31) = 4.17, p = .025, partial eta squared = .21, but not for coach ratings, F (2, 31) = 1.82, p = .18, partial eta squared = .11.

Relationships between CT Index, self-reported psychological states, and performance

Pearson's correlation coefficients revealed significant positive associations between player and coach ratings combined and both self-efficacy (r = .43, p < .01) and control (r = .41, p < .05). Significant positive associations were also found between coach ratings and self-efficacy (r = .43, p < .01) and, player ratings and control (r = .39, p < .05). All other correlations were non-significant (p > .05) and are shown in Table 1. The effect sizes associated with these correlations were small to medium (Cohen, 1992).

Changes in CV reactivity between Game 1 and Game 2

Of the 19 that were re-tested 10 responded consistently, of these 2 were challenged, 0 were threatened and, 8 were blunted. Of the 9 that responded inconsistently, 1 was challenged in time 1 and blunted in time 2, 1 was threatened in time 1 and blunted in time 2, 1 was blunted in time 1 and threatened in time 2 and, 6 were blunted in time 1 and challenged in time 2. A paired samples t-test indicated a moderate (Cohen's d = .44) but non-significant difference between the CT index at time 1 (M = -.13, SD = 1.07) and time 2 (M = .43, SD =

1.47); t (18) = -1.55, p = .14. Cronbach's Alpha also revealed a low level of internal consistency between testing time point 1 and 2 (α = .40).

Discussion

The present study supports previous research demonstrating the association between challenge reactivity and superior performance (e.g., Blascovich et al., 2004; Moore et al., 2012; Seery, Weisbuch, Hetenyi, & Blascovich, 2010; Turner et al., 2012; Turner et al., 2013). This is the first study to use repeated measures design to investigate challenge and threat states in professional athletes prior to competitive performance and overall, the results did not support the experimental hypothesis that CV responses would be inconsistent, although some participants did respond differently across the competitive matches suggesting some individual differences. Importantly, the current study extends the research in this area by examining psychophysiological data using a professional athlete sample in an imminent, real performance setting, building on previous work undertaken using self-report data (e.g. Moore et al., 2013), manufactured performance settings (e.g., Moore et al., 2012; Turner et al., 2012; Turner et al., 2013) and season long performances (Blascovich et al., 2004).

Greater challenge reactivity was positively and significantly associated with greater performance scores (for both player ratings and, coach and player ratings combined post-performance). These findings support the hypothesis that a soccer player in a challenge state prior to performance is more likely to perform better in the match. In a challenge state, efficient mobilisation of energy supports the individual to perform. A challenge state is proposed to be effective at facilitating improved decision-making, effective cognitive functioning, decreased likelihood of reinvestment, efficient self-regulation, and increased anaerobic power (Jones et al., 2009), all factors likely to contribute to the successful competitive performance of a soccer player. Recent research has linked challenge evaluation with greater anaerobic power compared to a threat evaluation (Wood, Parker, Freeman, Black, & Moore, 2018), however, it is important to note that to-date, there has been a little other research to support the TCTSA's assertions relating to decision-making, cognitive functioning, and anaerobic power.

The finding that player and combined ratings of performance were predicted by the CT index and not the coach ratings is an interesting outcome that has potential implications with regards to assessing challenge and threat states against performance and the reliability of coach ratings. A possible reason for this result includes the fact that players were only reflecting and rating on their own performance, whereas the coaches were likely to be focusing on numerous factors associated with the game and would be drawing on less information than a player rating themselves who would likely be more acutely aware of their actions.

The findings regarding changes in CV reactivity over time indicated that at time 2 participants evinced greater challenge CV reactivity. Whilst these changes were not reflected in statistical significant differences between time 1 and time 2, a moderate effect size was revealed. This is important because this analysis was subject to a low sample size, casting doubts on the utility of p as the marker of meaningful change. In addition, it was found that 10, of the 19 players who completed repeated measures responded consistently. However, only 2 were consistent in challenge or threat reactivity (both challenged) with the remaining 8 participants being consistent blunted responders. This does suggest that in this sample of soccer players, challenge and threat CV reactivity to stress does have some variability. Such variance in challenge and threat reactivity indicates support for the situational nature of challenge and threat appraisals in sport (e.g. Turner et al., 2013), and the idea that challenge and threat states can be manipulated by changing an individual's demand and resource appraisals. This also has implications more broadly beyond sport, whereby similar support could be provided to help those suffering from anxiety and mental health conditions to promote healthier stress responses and, to educate and equip individuals with skills to help them manage stressful life situations. The mixed response across participants in our exploratory analysis indicate that other variables, in addition to the presence of a motivated performance situation may influence a soccer players' psychophysiological response. Future research would look to explore whether such influences have an impact (i.e. the opponent, previous athlete form, crowd size etc.).

In the present study a number of participants demonstrated a blunted response and they performed worse. This could be because individuals with higher levels of anxiety present less cardiac reactivity, to the point of being blunted (Carroll, Phillips, Hunt, & Der, 2007). This may suggest that those individuals with a blunted response were in fact the most anxious about the game and accordingly performance was negatively affected. Alternatively, there are number of other potential reasons why an individual may have a blunted response to psychological stress. Exercise is purported to have an attenuating effect on an individual's HR reactivity at resting levels (e.g. Hocking, Schuler, & O'Brien, 1997; Porges, 1995), with individuals of higher fitness levels exhibiting a lesser HR response to psychological stress (e.g. Boutcher & Nugent, 1993; Spalding, Jeffers, Porges, & Hatfield, 2000). Further, Lovallo, Farag, Sorocco, Cohoon, and Vincent (2012) highlight how experiencing adversity in childhood can also lead to blunted CV reactivity. Such evidence could point to professional sportspeople being physiologically conditioned to exhibiting non-reactive CV responses to stressful situations; however, this would not account for those players who did react in the testing conditions.

The CV data supporting the hypothesis that a challenge state will facilitate a better performance for soccer players in an upcoming match has important implications for the sport of soccer as well as for other professional sports (e.g. Turner et al., 2013). Through understanding that a pre-performance state in an individual can influence their performance outcome, greater consideration and education can be provided to both athletes and staff as to how to facilitate a challenge state and avoid a threat state (i.e. through the appraisal process; Chalabaev, Major, Cury, & Sarrazin, 2009; Quested, Bosch, Burns, Cumming, Ntoumanis, & Duda, 2011). For instance, Turner et al. (2014), demonstrated that by manipulating pre-task instructions in a competitive throwing task and physically demanding task, challenge task instructions led to challenge cardiovascular reactivity and threat task instructions led to threat cardiovascular reactivity. Also, Sammy et al. (2017), demonstrated arousal reappraisal in a pressurised dart throwing task, led to more favourable cardiovascular reactivity, higher resource evaluations, and higher self-confidence in participants. Such findings have implications for facilitating challenge responses in motivated performance situations through the manipulation of appraisals.

There are some limitations to the current study, which can also be identified as areas of future research. Due to the number of players demonstrating reactivity, future research should potentially focus more on effective methodology of eliciting HR reactivity in participants. For instance, a familiar coach delivering the audio instructions (rather than an unknown voice), providing visual stimuli (clips of the individual in performance situations), and looking to conduct testing closer to the match (in the more relevant setting of a changing room) are all suggestions that could be employed to promote cognitions related to the imminent performance of the player in the upcoming match.

Only 19 players were exposed to repeated measures of the testing protocol. Ideally, this number would have been higher. However, logistically, obtaining 37 players (18 for single and 19 for repeated measures testing) was complicated and demanding in itself, given the level of planning and organisation that involved numerous stakeholders (drivers, catering, sport science team members, coaches etc.) on a match day in a professional soccer environment. Testing for a research study is not a priority for a soccer club, so the researcher is relying on the goodwill of staff and particularly, the players to be flexible towards the process. A power analysis using G*Power revealed that for regression analyses with a statistical power of .80 and an effect size of .21 (based on Behnke & Kaczmarek, 2018), 40 participants were required. Thus, future research would still benefit from a larger sample size, particularly with the repeated measures design in order to explore consistency in a larger sample. The resource appraisals were used as per the TCTSA (Jones et al., 2009), however, future research could explore situational demands (e.g. Mendes, Gray, Mendoza-Denton, Major & Epel, 2007).

Future research could also consider more objective outcomes of performance other than player and coach self-ratings, such as global positioning (GPS) data, number of errors, pass completion data. However, soccer is a complex game where it is difficult to validate performance levels against such data (i.e. a player may have ran more than team mates and have a high pass percentage completion but not made the best choices in terms of where they ran and who they passed to). Cardiovascular data was collected from players across games with varying kick-off times (e.g. 11am, 3pm, 7pm), and this could have had implications for individuals based on cortisol levels being associated with circadian rhythms (Chan & Debono, 2010). Whilst it may have been expected that player and coach ratings could differ based on subjectivity and different perspectives (i.e. performing in versus observing the match), the performance ratings across matches were similar during the research for these two sub-groups (Pearson's correlation analysis; $r = .52$, $p = 001$), subsequently, supporting the methodology of using a combined performance rating in the data analysis. Future research would also acknowledge the need identified in recent research (e.g. Hase et al., 2018), to provide greater examination of the relationship between demand resource evaluations and CV responses to motivated performance situations to provide a thorough examination of the TCTSA components (e.g., by using demand resource evaluation score; Vine, Moore, Chandra-Ramana, Freeman, & Wilson, 2013).

The results demonstrated that the association between psychological antecedents proposed by the TCTSA (self-report data) and CV responses was weak and inconsistent (e.g., players reporting significant physiological changes when the data highlighted blunted response), indicating that players' interpretation of their physiological reactions may not correspond to what they are actually experiencing. Of the self-report measures used, only self-efficacy and control were positively associated with performance, both demonstrating medium effect sizes (Cohen, 1992). This aligned with previous research failing to support the proposed relationships between challenge and threat antecedents, the psychological and cardiovascular indices of challenge and threat and resulting emotions (e.g. Meijen et al., 2013; Meijen, Jones, Sheffield, & McCarthy, 2014; Turner et al., 2012; Williams, Cumming, & Balanos, 2010). Such outcomes could be explained by challenge and threat states being potentially more difficult to assess via self-report measures than through CV reactivity (Chalabaev et al.,2009). Further, the social desirability present in professional sport, may cause participants to respond in a biased manner when answering questions related to psychological states (e.g. Williams & Krane, 1992). Also, it has been proposed that self-report is an ineffective methodology to examine how individuals process consciously available evaluations and provide no insight into processes that can occur unconsciously (e.g. Blascovich & Mendes, 2000; Turner et al., 2013). It has also been put forward that the language used in sport may not relate to the theoretical use of terms in self-report and, as such, may not reflect an individuals' psychological approach to performance (Meijen et al., 2013). However, Trotman et al. (2018) did find that associations between antecedents, self-report and cardiovascular indices of challenge and threat and emotions support the TCTSA for a competition task, but less so for a public speaking task. There were also significant positive associations between Batting Test performance and self-reported performance approach goals and self-efficacy in Turner et al.'s (2013) research. Such positive results indicate that further research is still required and suggestions to potentially improve the design could include collecting data closer to the actual match (i.e. prior to kick-off in the changing room) and, questionnaires being less susceptible to response bias or being able to assess deeper cognitions (Turner et al., 2013).

In summary, this is the first study to show that challenge and threat CV reactivity can predict sport performance in a competitive match in professional athletes. Such CV reactivity data could be useful for both players and their coaches to better understand their responses to pressure. This information could influence players and athletes towards seeking further understanding and assistance in strategies to support their ability to respond to situations of perceived pressure. In particular, as there were fluctuations in the CV reactivity for those participants whose data were collected on more than one occasion suggesting that some participants responded differently across the competitive matches.

Declaration of interest statement

As the first author was working full-time in the environment he was mindful to emphasise the voluntary nature of participation, highlighting that it would not impact any judgements made about the individual as a player or influence their progress in the academy. Some players turned down the request to participate.

No financial interest or benefits have arisen from the direct applications of this research.

References

Adie, J. W., Duda, J. L., & Ntoumanis, N. (2008). Autonomy support, basic need satisfaction, and the optimal functioning of adult male and female sport participants: a test of basic needs theory. *Motivation and Emotion, 32,* 189-199.

Behnke, M., & Kaczmarek, L. D. (2018). Successful performance and cardiovascular markers of challenge and threat: A meta-analysis. *International Journal of Psychophysiology 130,* 73–79.

Blascovich, J., Mendes, W. B., Vanman, E. & Dickerson, S. (2011). *Social Psychophysiology for Social and Personality Psychology.* London: Sage.

Blascovich, J., & Mendes, W. B. (2000). Challenge and threat appraisals: the role of affective cues. In J. P. Forgas (Ed.) *Feeling and thinking: the role of affect in social cognition (59-82).* Paris: Cambridge University Press.

Blascovich, J., Mendes, W. B., Hunter, S. B., & Salomon, K. (1999). Social "facilitation" as challenge and threat. *Journal of Personality and Social Psychology, 77,* 68-77.

Blascovich, J., Mendes, W. B., Tomaka, J., Salomon, K., & Seery, M. (2003). The robust nature of the biopsychosocial model challenge and threat: A reply to Wright and Kirby. *Personality and Social Psychology Review, 7,* 234-243.

Blascovich, J., Seery, M. D., Mugridge, C. A., Norris, R. K., & Weisbuch, M. (2004). Predicting athletic performance from cardiovascular indexes of challenge and threat. *Journal of Experimental Social Psychology, 40,* 683- 688.

Blascovich, J., & Tomaka, J. (1996). The biopsychosocial model of arousal regulation. *Advances in Experimental Social Psychology, 28,* 1-51.

Boutcher, S. H., & Nugent, F. W. (1993). Cardiac response of trained and untrained males to a repeated psychological stressor. *Journal of Behavioral Medicine, 19,* 21-7.

Carroll, D., Phillips, A.C., Hunt, K., Der, G. (2007). Symptoms of depression and cardiovascular reactions to acute psychological stress: evidence from a population study. *Biological Psychology, 75,* 68–74.

Chalabaev, A., Major, B., Cury, F., & Sarrazin, P. (2009). Physiological markers of challenge and threat mediate the effects of performance-based goals on performance. *Journal of Experimental Social Psychology, 45,* 991-994.

Chan, S., & Debono, M. (2010). Review: Replication of cortisol circadian rhythm: new advances in hydrocortisone replacement therapy. *Therapeutic Advances in Endocrinology and Metabolism, 1,* 129–138.

Coffee, P., & Rees, T. (2008). Main and interactive effects of controllability and generalisability attributions upon self-efficacy. *Psychology of Sport and Exercise, 9,* 775–785.

Cohen, J. (1992). A power primer. *Psychological Bulletin, 112,* 155–159.

Conroy, D. E., Elliot, A. J., & Hofer, S. M. (2003). A 2 x 2 achievement goals questionnaire for sport: Evidence for factorial invariance, temporal stability, and external validity. *Journal of Sport and Exercise Psychology, 25,* 456-476.

Cumming, S., Turner, M. J., & Jones, M. V. (2017). Longitudinal changes in elite rowers' challenge and threat appraisals of pressure situations: A season-long observational study, *The Sport Psychologist, 31,* 217-226.

Dienstbier, R. A. (1989). Arousal and physiological toughness: Implications for mental and physical health. *Psychological Review, 96,* 84-100.

Epel, E. S., Crosswell, A. D., Mayer, S. E., Prather, A. A., Slavich, G. M., Puterman, E, Mendes, W. B. (2018). More than a feeling: A unified view of stress measurement for population science. *Frontiers in Neuroendocrinology*, *49,* 146–169.

Gouttebarge, V., Frings-Dresen, M. H., & Sluiter, J. K. (2015). Mental and psychosocial health among current and former professional footballers. *Occupational Medicine, 65,* 190-196.

Hase, A., O'Brien, J., Moore, L., & Freeman, P. (2018). The relationship between challenge and threat states and performance: A systematic review. *Sport, Exercise, and Performance Psychology.* DOI: 10.1037/spy0000132

Hocking Schuler, J. L., & O'Brien, W. H. (1997). Cardiovascular recovery from stress and hypertension risk factors: A meta-analytic review. *Psychophysiology, 34,* 649–659.

Holt, N., & Hogg, J. (2002). Perceptions of stress and coping during preparations for the 1999 women's soccer World Cup finals. *Sport Psychologist, 16,* 251-271.

Jones, M.V., Lane, A.M., Bray, S., Uphill, M.A., & Caitlin, J. (2005). Development and validation of the Sport Emotions Questionnaire. *Journal of Sport and Exercise Psychology, 27*, 407-431.

Jones, M. V., Meijen, C., McCarthy, P. J., & Sheffield, D. (2009). A theory of challenge and threat states in athletes. *International Review of Sport and Exercise Psychology, 2,* 161-180.

Jordet G., Hartman, E., Visscher, C., Lemmink, K. A. (2007). Kicks from the penalty mark in soccer: the roles of stress, skill, and fatigue for kick outcomes. *Journal of Sports Sciences, 25,* 121-9.

Lazarus, R. S., & Folkman, S. (1984). *Stress, appraisal, and coping.* New York, NY: Springer.

Lovallo, W. R. (2013). Early life adversity reduces stress reactivity and enhances impulsive behavior: Implications for health behaviors. *International Journal of Psychophysiology, 90,* 8-16.

Lovallo, W. R., Farag, N. H., Sorocco K. H., Cohoon A. J., & Vincent A. S. (2012). Lifetime adversity leads to blunted stress axis reactivity: studies from the Oklahoma family health patterns project. *Biological Psychiatry, 71*, 344–349.

McGregor, H. A., & Elliot, A. J. (2002). Achievement goals as predictors of achievement-relevant processes prior to task engagement. *Journal of Educational Psychology, 94,* 381-395.

Meijen, C., Jones, M. V., McCarthy, P. J., Sheffield, D., & Allen, M. S. (2013). Cognitive and affective components of challenge and threat states. *Journal of Sports Sciences, 31,* 847–855.

Meijen, C., Jones, M. V., Sheffield, D., & McCarthy, P. J. (2014). Challenge and threat states: Cardiovascular, affective, and cognitive responses to a sports-related speech task. *Motivation and Emotion, 38.* 252-262.

Mendes, W. B., Gray, H. M., Mendoza-Denton, R., Major, B., & Epel, E. S. (2007). Why Egalitarianism Might Be Good for Your Health: Physiological Thriving During Stressful Intergroup Encounters. *Psychological Science, 18,* 991–998.

Mendes, W. B., Major, B., McCoy, S., & Blascovich, J. (2008). How attributional ambiguity shapes physiological and emotional responses to social rejection and acceptance. *Journal of Personality and Social Psychology, 94,* 278-291.

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

Moore, L. J., Vine, S. J., Wilson, M. R., & Freeman, P. (2012). The effect of challenge and threat states on performance: An examination of potential mechanisms. *Psychophysiology, 49,* 1417-1425.

Perry, R. P., Hladkyj, S., Pekrun, R. H., & Pelletier, S. T. (2001). Academic control and action control in the achievement of college students: A longitudinal field study. *Journal of Educational Psychology, 93,* 776–789.

Phillips, A., Ginty, A., & Hughes, B. (2013). The other side of the coin: Blunted cardiovascular and cortisol reactivity are associated with negative health outcomes. *International journal of psychophysiology: official journal of the International Organization of Psychophysiology, 90,* 1-7.

Porges, S. W. (1995). Cardiac vagal tone: a physiological index of stress. *Neuroscience & Biobehavioral Reviews, 19,* 225–233.

Quested, E., Bosch, J. A., Burns, V. E., Cumming, J., Ntoumanis, N., & Duda, J. L. (2011). Basic psychological need satisfaction, stress-related appraisals, and dancers' cortisol and anxiety responses. *Journal of Sport & Exercise Psychology, 33,* 828-846.

Quigley, K. S., Barrett, L. F., & Weinstein, S. (2002). Cardiovascular patterns associated with threat and challenge appraisals: Individual responses across time. *Psychophysiology, 39,* 1-11.

Sammy, N., Anstiss, P., Moore, L., Freeman, P., Wilson, M., & Vine, S. (2017). The effects of arousal reappraisal on stress responses, performance, and attention. *Anxiety Stress and Coping, 30,* 1-20.

Seery, M. D. (2011). Challenge or threat? Cardiovascular indexes of resilience and vulnerability to potential stress in humans. *Neuroscience and Biobehavioral Reviews, 35,* 1603-1610.

Seery, M. D., Holman, E. A., & Silver, R. C. (2010). Whatever does not kill us: Cumulative lifetime adversity, vulnerability, and resilience. *Journal of Personality and Social Psychology, 99,* 1025-1041.

Seery, M. D., Weisbuch, M., Hetenyi, M. A., & Blascovich, J. (2010). Cardiovascular measures independently predict performance in a university course. *Psychophysiology, 47,* 535–539.

Spalding, T. W., Jeffers, L. S., Porges, S. W., & Hatfield, B. D. (2000). Vagal and cardiac reactivity to psychological stressors in trained and untrained men. *Medicine & Science in Sports & Exercise, 32,* 581-91.

Tomaka, J., Blascovich, J., Kelsey, R. M., & Leitten, C. L. (1993). Subjective, physiological, and behavioral effects of threat and challenge appraisal. *Journal of Personality and Social Psychology, 65,* 248-260.

Tomaka, J., Blascovich, J., Kibler, J., & Ernst, J. M. (1997). Cognitive and physiological antecedents of threat and challenge appraisal. *Journal of Personality and Social Psychology, 73,* 63-72.

Trotman, G. P., Williams, S. E., Quinton, M. L., & Veldhuijzen van Zanten, J. J. C. S. (2018). Challenge and threat states: examining cardiovascular, cognitive, and affective responses to two distinct laboratory stress tasks. *International journal of psychophysiology: official journal of the International Organization of Psychophysiology, 126,* 42-51.

Turner M. J., Jones M. V., Sheffield, D., Barker J. B., & Coffee P. (2014). Manipulating cardiovascular indices of challenge and threat using resource appraisals. *International Journal of Psychophysiology, 94,* 9-18.

Turner, M. J., Jones, M. V., Sheffield, D., & Cross, S. L. (2012). Cardiovascular indices of challenge and threat states predict performance under stress in cognitive and motor tasks. *International Journal of Psychophysiology, 86,* 48-57.

Turner, M. J., Jones, M. V., Sheffield, D., Slater, M. J., Barker, J.B., & Bell, J. J. (2013). Who Thrives Under Pressure? Predicting the Performance of Elite Academy Cricketers Using the Cardiovascular Indicators of Challenges and Threat States. *Journal of Sport & Exercise Psychology, 35,* 387-397.

Vine S. J., Moore LJ, Chandra-Ramana R., Freeman P., & Wilson, M. R. (2013). Evaluating stress as a challenge is associated with superior attentional control and motor skill performance: Testing the predictions of the biopsychosocial model of challenge and threat. *Journal of Experimental Psychology: Applied, 19,* 185-194.

Williams, J. M., & Krane, V. (1992). Coping styles and self-reported measures of state anxiety and self-confidence. Journal of Applied Sport Psychology. *Journal of Applied Sport Psychology, 4,* 134-143.

Williams, S. E., Cumming, J., & Balanos, G. M. (2010). The use of imagery to manipulate challenge and threat appraisal states in athletes. *Journal of Sport & Exercise Psychology, 32,* 339–358.

Williams, S. E., Veldhuijzen van Zanten, J. J. C. S., Trotman, G. P., Quinton, M. L., & Ginty, A. T. (2017). Challenge and threat imagery manipulates heart rate and anxiety responses to stress. *International Journal of Psychophysiology. 117,* 111-118.

Wood, N., Parker, J. K., Freeman, P., Black, M., & Moore, L. (2018). The relationship between challenge and threat states and anaerobic power, core affect, perceived exertion, and self-focused attention during a competitive sprint cycling task. *Progress in Brain Research, 240,* 1-17.

Table 1. Mean ± SD and Correlation Analyses for Performance, Psychological Variables, and the Challenge and Threat Index for Time 1

Variable	*M ± SD*	Challenge & Threat Index (*β* Value from Coefficients)	Performance: Coach & Player Ratings Combined	Performance: Coach Ratings	Performance: Player Ratings
HR (average baseline)	65.17 ± 11.01	-	-	-	-
HR (two mins. post instructions)	67.32 ± 11.29	-	-	-	-
CO (average baseline)	5.89 ± 1.26	-	-	-	-
CO (two mins. post instructions)	6.11 ± 1.41	-	-	-	-
TPR (average baseline)	1.333.38 ± 317.27	-	-	-	-
TPR (two mins. post instructions)	1355.48 ± 337.15	-	-	-	-
Player & Coach Rating	70.58 ± 12.79	.57*	-	-	-
Coach Rating	70.75 ± 15.33	.42	-	-	-
Player Rating	70.40 ± 14.40	.57*	-	-	-
Years of Experience	10.86 ± 2.31	.01	-.30	-.22	-.31
Age	18.19 ± 1.37	.40	-.06	.07	-.17
Self-efficacy	82.36 ± 13.21	.18	.43**	.43**	.33
Control	82.10 ± 13.13	.09	.41*	.31	.39*
Mastery-approach goals (MAp)	6.66 ± .59	.25	.10	.10	.08
Mastery-avoidance goals (MAv)	3.78 ± 1.66	.13	-.02	-.14	.08
Performance-approach goals (PAp)	5.09 ± 1.59	.05	.21	.05	.28
Performance-avoidance goals (PAv)	2.76 ± 1.72	.15	.11	.01	.17
Anxiety	1.03 ± .75	.14	-.20	-.31	-.08
Excitement	2.61 ± .91	.10	.31	.18	.33

*$p < .05$

**$p < .01$

Table 2. Mean ± SD Data for Performance Ratings of Participants for Time 1

* p <.05

	Player Performance Rating		Coach Performance Rating		Combined Performance Rating	
	Mean	**SD**	**Mean**	**SD**	**Mean**	**SD**
Challenge	74.67*	7.89	74.44	16.29	74.56**	9.99
Threat	66.91	17.73	67.73	14.55	67.32	14.32
Blunted	61.56*	18.97	64.38	10.31	62.97**	13.09

** p <.05