Turner MJ, Jones MV, Sheffield D, Barker J & Coffee P (2014) Manipulating cardiovascular indices of challenge and threat using resource appraisals, *International Journal of Psychophysiology*, 94 (1), pp. 9-18..

This is the peer reviewed version of this article

Manipulating cardiovascular indices of challenge and threat using resource appraisals

Date of Resubmission: 2nd June 2014

Martin J. Turner[a], Marc V. Jones[a], David Sheffield[b], Jamie B. Barker[a], & Peter Coffee[c]

[a]Centre for Sport, Health, and Exercise Research, Staffordshire University, B128, Brindley Building, Leek Road, Stoke On Trent, Staffordshire ST4 2DF, UK

[b]Centre for Psychological Research, Faculty of Education, Health and Sciences, University of Derby, Kedleston Road, Derby, DE22 1GB, UK

[c]School of Sport, University of Stirling, Stirling, FK9 4LA, Scotland, UK

Contact Details:

Martin J. Turner: martin.turner@staffs.ac.uk, 07908298494

Marc V. Jones: marc.jones@staffs.ac.uk, +44 (0) 1782295985

David Sheffield: D.Sheffield@derby.ac.uk, +44 (0) 1332 591703

Jamie B. Barker: J.B.Barker@staffs.ac.uk, +44 (0) 1782295810

Peter Coffee: peter.coffee@stir.ac.uk, + 44 (0) 1786 466253

Abstract

Challenge and threat reflect two distinct psychophysiological approaches to motivated performance situations. Challenge is related to superior performance in a range of tasks compared to threat, thus methods to promote challenge are valuable. In this paper we manipulate challenge and threat cardiovascular reactivity using only resource appraisals, without altering perceived task demands between challenge and threat conditions. Study 1 used a competitive throwing task and Study 2 used a physically demanding climbing task. In both studies challenge task instructions led to challenge cardiovascular reactivity and threat task instructions led to threat cardiovascular reactivity. In study 1, participants who received challenge instructions performed better than participants who received threat instructions. In study 2, attendance at the climbing task did not differ across groups. The findings have implications for stress management in terms of focusing on manipulating appraisals of upcoming tasks by promoting self-efficacy and perceived control, and focusing on approach goals. Future research could more reliably assess the influence of similar task instructions on performance.

Keywords: Theory of Challenge and Threat States in Athletes, Biopsychosocial model, cardiovascular reactivity, cognitive appraisal, emotion.

Manipulating cardiovascular indices of challenge and threat using resource appraisals

Challenge and threat are two distinct psychophysiological responses to stressors (see Blascovich, Mendes, Vanman, & Dickerson, 2011; Seery, 2011). Challenge is considered an adaptive approach to a motivated performance situation (e.g., a stressor such as competition), occurring when personal resources meet or exceed perceived situational demands. Threat is considered a maladaptive approach to a motivated performance situation, occurring when personal resources do not meet perceived situational demands (Blascovich & Mendes, 2000). Predictably, research has attempted to promote challenge, and many investigations have used instructional sets concerning an upcoming stressor or task to do so (e.g., Tomaka, Blascovich, Kibler, & Ernst, 1997). Research that indicates that challenge can be promoted using challenge task instructions has valuable implications for stress management. This paper reports the use of instructional sets that manipulate individuals' appraisals of personal resources, specifically self-efficacy, perceived control, and achievement goals as proposed within the Theory of Challenge and Threat States in Athletes (TCTSA; Jones, Meijen, McCarthy, & Sheffield, 2009). In short, this paper offers a methodological advance in the promotion of challenge states in a sport-related setting.

Challenge and threat are underpinned by cognitive appraisal, proposed by Lazarus (1991) to be the perceptual mediator between stressor and stress response, a notion widely accepted in theory and supported by empirical research (e.g., Holmes & Houston, 1974; Koriat, Melkman, Averill, & Lazarus, 1971; Nisbett & Schachter, 1966; Speisman, Lazarus, Davidson, & Mardkott, 1964). In addition, the idea that differences in stress responses can be indexed via cardiovascular (CV) markers is also widely recognized (e.g., Blascovich et al., 2011; Seery, 2011), and helps to illuminate the relationship between perception and physiological stress responses, by offering objective physiological markers of challenge and threat appraisals. Challenge cognitive appraisals are associated with challenge CV reactivity and threat cognitive appraisals are associated with threat CV reactivity (Blascovich & Mendes, 2000). The measurement of challenge and threat CV reactivity offers a more objective measure of challenge and threat, which is important because previous research has indicated that self-reported psychological states are sensitive to social desirability (Paunonen & LeBel, 2012), do not always correlate with CV reactivity (e.g., Martinek, Oberascher-Holzinger, Weishuhn, Klimesch, & Kerschbaum, 2003; Turner, Jones, Sheffield, & Cross, 2012), and may not always reflect complex and often unconscious mental processes (LeDoux, 1998).

In the BPS model of challenge and threat (Blascovich & Mendes, 2000) challenge is accompanied by increased catecholamine output (epinephrine and norepinephrine) indicating sympathetic adreno-medullary (SAM) activity, which is reflected in increased heart rate (HR) and cardiac output (CO), attenuated preejection period (PEP), and decreased total peripheral resistance (TPR). This challenge CV reactivity pattern represents an efficient physiological response to stressors, where the energy needed for successful performance (e.g., glucose) is released into the blood, and can reach the brain and muscles efficiently due to decreased vascular resistance and enhanced blood flow (Dienstbier, 1989, 1992). Threat is also marked by increased SAM activity, but is characterised by increased pituitary adreno-cortical (PAC) activity, resulting in cortisol release (e.g., Jamieson, Koslov, Nock, & Mendes, 2012). Thus, increased HR and attenuated PEP occurs, which indexes task engagement in both challenge and threat, but with an increase or stabilisation in TPR, and a small increase, decrease, or stabilisation in CO. In this threat CV reactivity pattern PAC activity is thought to temper SAM activity, therefore compared to a challenge CV reactivity pattern, efficient energy delivery to the brain and muscles does not occur (Dienstbier, 1989, 1992). A consistent body of evidence supports the BPS model (see Blascovich et al., 2011; Seery, 2011 for reviews). For clarity, challenge CV reactivity is reflected in increased CO and decreased TPR, and threat CV reactivity is reflected in a small increase, stabilisation, or decreased in CO and increased TPR.

Lazarus and Folkman (1984) introduced the concepts of challenge and threat as two possible cognitive appraisals leading to two different stress responses. Threat cognitive appraisals occur when secondary appraisal indicates that an individual's coping potential is not sufficient, thus deeming harm potentially imminent. Challenge cognitive appraisals occur when secondary appraisal indicates that an individual's coping potential is sufficient, thus deeming harm less likely. Challenge is considered an adaptive approach associated with superior performance, and threat a maladaptive approach associated with inferior performance in a range of tasks (e.g., Blascovich, Seery, Mugridge, Norris, & Weisbuch, 2004; Moore, Vine, Wilson, & Freeman, 2012; Schneider, 2008; Turner, Jones, Sheffield, & Cross, 2012; Turner, Jones, Sheffield, Slater, Barker, & Bell, 2013).

To manipulate challenge and threat research has successfully used challenge and threat instructional sets (e.g., Hemenover & Dienstbier, 1996; Feinberg & Aiello, 2010; Taylor & Scogin, 1992; Tomaka et al., 1997). For example, Tomaka et al. (1997) used threat instructions that informed participants that "it is very important that you perform the task as quickly and efficiently as possible" and instructed participants that "you must keep going until the task is completed" (p. 72). It should be noted that the threat instructions do not manipulate demand or resource appraisals but appear to have manipulated task importance. Challenge instructions encouraged participants to "try really hard to do your best," to "think of the task as a challenge to be met," and to "think of yourself as someone capable of meeting that challenge" (p. 72). Challenge instructions led to challenge appraisals and challenge CV reactivity and threat instructions to threat appraisal and threat CV reactivity to a mental arithmetic task, demonstrating the influence instructional sets could have on challenge and threat. Tomaka et al. chose to manipulate both demand and resource appraisals in their instructional sets, and also adopted an encouraging and supportive tone in the challenge instructions compared to the threat instructions. That is, threat instructions were delivered in a “staccato and stern tone” while challenge instructions were delivered “in a much more pleasant way” (Blascovich & Mendes, 2000, p. 75). Tomaka et al. show how the content and tone of instructional sets can be important in promoting challenge.

In another paper (Feinberg & Aiello, 2010), challenge instructions informed participants to “try hard to do your best” in an upcoming math/anagram task, to “think of yourself as someone capable of meeting the challenges of this task,” and informed participants that “most participants are able to handle the tasks” (p. 2104). Threat instructions informed participants that “many participants have trouble performing well on this task” that “it is important that you perform this task as quickly and efficiently as possible” as “both speed and accuracy of your answers will be examined” (p. 2104). Feinberg and Aiello (2010), like Tomaka et al. (1997), emphasized task demands and offered little encouragement in the threat instructions compared to challenge instructions, offering further support for the notion that challenge can be promoted by altering perceived task demands.

In sum, past research has successfully manipulated challenge and threat using a range of instructional sets that focus either on altering perceived demands of an upcoming task, or in one study, altering perceived task importance, perceived demands, and perceived resources (e.g., Tomaka et al., 1997). In addition, the differing tone in which instructional sets are delivered may have contributed to the manipulation of challenge and threat in some studies (e.g., Tomaka et al., 1997). Because demand appraisals (requirement for effort, uncertainty, and danger to esteem) are usually salient in motivated performance situations, attempts to devalue perceived task demands, whilst effective in laboratory studies, may be less effective in actual motivated performance situations. Therefore, in this paper we seek to manipulate challenge and threat states using task instructions that alter perceptions of personal resources without altering perceived task demands, and are more analogous between task instruction conditions. That is, instead of altering the requirement for effort, uncertainty, and danger to esteem (demand appraisal), or differing the tone of the instructions between conditions, the instructional sets used in the studies comprising this current paper seek to change self-efficacy, perceived control, and achievement goals, collectively known as the resource appraisals in the TCTSA (Jones et al., 2009).

The present paper examines an extension to the cognitive appraisal concepts used in the BPS model as proposed in the TCTSA (Jones et al., 2009). To explain, the TCTSA adopts the demand appraisals from the Biopsychosocial (BPS) model of challenge and threat (Blascovich & Mendes, 2000), but then outlines the resource appraisals, which comprise self-efficacy, perceived control, and achievement goals. On approaching a motivated performance situation high levels of self-efficacy, perceived control, and a focus on approach goals are posited to underpin challenge, while low levels of self-efficacy, perceived control, and a focus on avoidance goals are posited to underpin threat. However, to date research has not consistently shown these resource appraisals to correlate with challenge and threat CV reactivity in the manner predicted by the TCTSA (Meijen et al., 2013; Turner et al., 2012; 2013), but consistent with broader evidence that self-reports may not always relate to physiological reactivity (e.g., Martinek et al., 2003). Although some studies that have manipulated challenge and threat states have reported concomitant changes in self-report measures (e.g., Moore et al., 2012).

By adopting only the resource appraisals to manipulate challenge and threat CV reactivity in the present study, we propose to maintain the perceived demands of the situation, thus offering an alternative method of manipulating challenge and threat states to previous research that may be applicable in situations where the manipulation of task demands is not possible. For example, it may be very difficult to convince a person who has an upcoming interview for a promotion that the situation will not be demanding and difficult, and is not important for her career. In addition, suggesting that she simply do her best may be insufficient to counter the importance of the potential promotion. In fact, it is often precisely the importance of an event that provides the motivation to succeed (e.g., Eysenck & Calvo, 1992). Finding strategies to successfully promote challenge reactivity in motivated performance situations without altering the perceived demands is a valuable endeavour, as a growing body of research reports the association between challenge reactivity and superior performance compared to threat reactivity (e.g., Blascovich et al., 2004; Moore et al., 2012; Seery, Weisbuch, Hetenyi, & Blascovich, 2010; Turner et al., 2012; Turner et al., 2013). For example, Turner et al. (2012) found that challenge CV reactivity was associated with increased performance from base levels in both a cognitive (Stroop Test) and a motor (Netball shooting) task, whereas threat CV reactivity was associated with decreased performance from base levels in both tasks.

The current paper presents two studies that examine whether challenge task instructions yield challenge reactivity, and whether threat task instructions yield threat reactivity, when perceived task demands were underpinned by competitive (Study 1) and physically demanding (Study 2) properties. In Study 1 a novel bean-bag throwing task was performed under competitive conditions to create a motivated performance situation. A novel task was used so that participants would not have prior task experiences that may nullify the effects of the task instructions. In Study 2 a physically demanding climbing task (also novel to participants) was used to create a situation in which there was danger of actual harm, rather than danger to esteem through social comparison as in Study 1. Climbing has been used several times in research to assess both physiological and psychological aspects of emotions and performance (e.g., Hardy & Hutchinson, 2007; Janot, Steffen, Porcari, & Maher, 2000; Jones, Mace, Bray, MacRae, & Stockbridge, 2002). Climbing is also a suitable task because climbers need to use complex problem solving skills in order to succeed and considerable physical effort is required to calculate how to perform complex movements (Hardy & Hutchinson, 2007; Janot et al., 2000).

In both Study 1 and Study 2, the resource appraisals proposed in the TCTSA were varied between challenge and threat instructions, but perceived task demands were kept constant between conditions. Based upon the TCTSA it was hypothesized that challenge task instructions would yield CV reactivity associated with challenge (i.e., decreased TPR and increased CO), and threat task instructions would yield CV reactivity associated with threat (i.e., increased TPR and decreased or stable CO). Based on consistent evidence linking challenge reactivity and superior motor performance (e.g., Blascovich et al., 2004; Moore et al., 2012; Turner et al., 2012; 2013), we also hypothesized that challenge instructions would result in superior performance compared to threat instructions. Self-reported resource appraisals were also measured, but as self-report measures do not consistently relate to challenge and threat reactivity (e.g., Meijen et al., 2013; Weisbuch et al., 2009) we did not hypothesize differences between challenge and threat instruction conditions.

1. Study 1

2. Methods

2.1. Participants

Forty six (*Female* = 22, *Male* = 24) UK University undergraduate students and academic staff (*M*age = 21.7years, *SD*age = 3.40years) were randomly and unknowingly allocated to either a challenge (*N* = 23; *Female* = 10, *Male* = 13) or threat (*N* = 23; *Female* = 12, *Male* = 11) task instruction condition[1], via systematic assignment. All participants were normotensive and reported being in good health. Ethical approval was granted from the University and informed consent was obtained prior to data collection. Participants were told that by taking part they could win £10 in shopping vouchers.

2.2. Measures

2.2.1. Cardiovascular

A Bio-Impedance cardiograph integrated system (model HIC-3004), along with a blood pressure (BP) monitor (Suntech Tango+) was used to measure all CV responses (Sherwood, 1993). Impedance cardiographic (ZKG) and electrocardiographic (ECG) recordings provided continuous measurement of CV performance. Impedance cardiograph measurement utilized a tetra-polar band electrode configuration widely used in similar research (see Blascovich et al., 2011). External ECG recordings were obtained using a Lead II configuration (right arm, left arm, and left leg). CopWin integrated the ZKG, ECG, and BP recordings to provide the four CV indices that differentiate challenge and threat; HR (bpm), PEP (ms), CO (l/minute), and TPR (dyn.s.cm^{-5}). CO is derived from stroke volume (SV) and HR (CO = SV x HR), and TPR is derived from mean arterial pressure (MAP; average blood pressure) and CO (TPR = [MAP/CO] x 80).

2.2.2. Emotions

The Sport Emotion Questionnaire (SEQ; Jones, Lane, Bray, Uphill, & Catlin, 2005) is a 22 item measure assessing anger (4 items), anxiety (5 items), dejection (5 items), excitement (4 items), and happiness (4 items). Only anxiety, excitement, and happiness were assessed in present study as anger and dejection typically do not occur pre-task (cf. Turner et al., 2012). Participants were asked to indicate “how you feel right now at this moment in relation to the upcoming bean-bag throwing task” on a 5-point Likert-scale ranging from 0 (*Not at all*) to 4 (*Extremely*). Cronbach’s alpha for the SEQ subscales from the current sample were: anxiety = .90, excitement = .75, and happiness = .81.

2.2.3. Achievement goals

The Achievement Goals Questionnaire (AGQ: Conroy, Elliot, & Hofer, 2003) consists of twelve questions with three questions per subscale; Mastery Approach (MAp), Mastery Avoidance (MAv), Performance Approach (PAp), and Performance Avoidance (PAv). The AGQ was modified for the present study by asking participants to indicate their thoughts and feelings about the upcoming bean-bag throwing task. Reponses were made on a 7-point Likert-scale ranging from 1 (*Not at all true*) to 7 (*Very true*). Cronbach's alpha for the AGQ subscales from the current sample were: MAp = .65, MAv = .90, PAp = .93, PAv = .86, which is in line with previous research (Muis & Winne, 2012).

2.2.4. Self-efficacy

A Self-Efficacy Scale (SES) was developed in line with suggested guidelines (Bandura, 2006) and comprised seven items relating to successful performance in the bean-bag throwing task. The seven items were: hit the centre of the target and score highly, stay focused, mobilize all your resources, perform well even if things get tough, raise the level of your performance, stay motivated, and throw the bean-bag accurately. Participants responded by rating how confident they felt executing each skill in the upcoming bean-bag throwing task. Responses were made on a 5-point Likert-scale ranging from 1 (*Not at all*) to 5 (*Completely*). A self-efficacy score was calculated by averaging the seven scores. Cronbach's alpha for the SES from the current sample was .87.

2.2.5. Perceived control

Participants completed one item, adapted from the Academic Control Scale (Perry, Hladkyj, Pekrun, & Pelletier, 2001) in which they rated how much they agreed with the statement, "The more effort I put into this task, the better I will do," on a 5-point Likert-scale ranging from 1 (*No control*) to 5 (*Total control*).

2.2.6. Task importance

Participants completed a single item indicating "how important doing well in the task was to them" on a 6-point Likert-scale ranging from 0 (*Not at all*) to 5 (*Very much so*).

2.2.7. Cognitive appraisal

Bases on past research (e.g., Tomaka et al., 1997) a single item was used to assess how threatening participants expected the task to be. In addition, participants were also asked how challenging participants expected the task to be to offer a comparative item. Items were: how threatening do you expect the upcoming Bean-Bag Throwing Test to be, and how challenging do you expect the upcoming Bean-Bag Throwing Test to be? Scores were recorded on a 6-point Likert-scale ranging from 0 (*Not at all*) to 5 (*Very much so*).

2.2.8. Bean-bag throwing task performance

The bean-bag throwing task consisted of 10 throws with the non-dominant arm toward a target on the floor six meters away from the throwing position. The target comprised a centre circle worth 10 points, surrounded by four concentric circles worth 8, 6, 4, and 2 points respectively. Zero points were scored outside of the circles. Higher scores indicated better performance, with a possible maximum total score of 100 and minimum of 0.

2.3. Procedures

2.3.1. Laboratory set-up

Data collection took place in a laboratory on the university campus. Participants were asked to refrain from participating in heavy exercise in the 24 hours prior to data collection and to refrain from consuming caffeine, food, and sports drinks in the two hours preceding data collection. Prior to arrival participants were randomly allocated to either the challenge or threat condition. On entry to the lab participants were given a brief outline of the protocol to desensitize them to the environment and demystify the equipment.

2.3.2. Participant preparation

Participants were prepared following relevant guidelines (Blascovich et al., 2011; Sherwood, 1993) and connected to the cardiogram. The participants were then informed that a five-minute rest period would commence in which CV data would be collected, after which they would hear a set of audio-instructions via a set of PC speakers. Participants were asked to sit upright, remain as still as possible, keep their arm rested on a support set at heart level, and to keep their feet at a ninety degree angle facing forward.

2.3.3. Cardiovascular and psychological data collection

CV data recording took place through baseline, task instruction, and mental preparation phases. After five minutes of baseline data collection participants were informed that the task instructions would begin. Then, participants listened to one of two audio-taped instructions about an upcoming bean-bag throwing task, depending on which condition they were allocated. Audio instructions lasted for two minutes (available on request from the first author), in which high task demands were promoted for both conditions, typical of the majority of motivated performance situations. Participants were informed that the task was difficult (thus requiring effort), was an important indicator of human movement (danger to esteem), with the novel nature of the task aimed at promoting perceptions of uncertainty regarding performance. As well as promoting task demands, the instructions contained the challenge or threat manipulation, in line with the resource appraisals put forth in the TCTSA (Jones et al., 2009). Challenge instructions informed participants that "*you will have performed similar throwing tasks in the past. Because of this experience, you can feel confident that you will score highly"* (promoting high self-efficacy), to *"try your upmost to hit the centre of the target"* (promoting a focus on approach goals) and that "*the equipment is set up to allow you to complete the task without complications"* (promoting high perceptions of control). Threat instructions informed participants that "*It is unlikely you will have done a task like this before so you obviously can't be sure that you will perform well*" (promoting low self-efficacy), to "*avoid the low scoring areas of the target"* (promoting a focus on avoidance goals), and that *"the bean-bags vary in weight which influences their flight"* (promoting low perceptions of control). The final part of the task instructions asked participants to mentally prepare for the upcoming bean-bag throwing task by thinking about their performance for two minutes. To be clear, there were four minutes in total for which CV data were recorded throughout. After CV data had been collected, participants completed the self-report measures in relation to the upcoming bean-bag throwing task and then participants completed the bean-bag throwing task.

2.3.4. Bean-bag throwing task

Once participants had completed the questionnaires, all equipment was removed so they could perform the task. Participants were then directed to the bean-bags and the location from which they would throw, and asked to begin. The score was recorded after each throw, and the task ended when participants had thrown all bean-bags. Participants were then debriefed before departing.

3. Analytic Strategy

Prior to main analyses separate Shapiro Wilks tests were performed for each condition. If outliers were present then z scores for significant outliers were assessed (Mendes, Reis, Seery, & Blascovich, 2003; Seery, West, Weisbuch, & Blascovich, 2008). Data with z scores greater than two were omitted from further analyses. The analytic strategy for all data comprised two steps. First, in line with previous studies using a similar protocol (e.g., Mendes et al., 2003; Turner et al., 2012), HR and PEP in the first minute of the post-task instruction phase was compared to HR and PEP in the fifth minute of baseline. This was to determine engagement in the task. Second, to test our hypotheses separate independent *t*-tests were conducted for CV reactivity and performance (bean-bag throwing score) to assess hypothesized differences between challenge and threat task instruction conditions. As is common in challenge and threat research, CV reactivity scores were calculated for CO and TPR by subtracting the raw CV responses for the last minute of baseline from the raw CV responses for the periods of time of interest (Seery, Blascovich, Weisbuch, & Vick, 2004; Seery et al., 2009). For example, the average CV reactivity data for the entire post-task instruction phase (four minutes) was subtracted from the fifth minute of baseline data. Third, separate independent *t*-tests were conducted to assess differences in self-report variables between challenge and threat task instruction conditions. All multicollinearity, homogeneity, normality and outlier checks met the assumptions necessary for all data analysis.

4. Results

4.1. Task engagement

Two separate paired samples *t*-tests were conducted and Cohen's *d* calculated (Cohen, 1992; values of .2 = small effect, .5 = medium effect, and .8 = large effect) to compare the fifth minute of baseline HR and PEP with HR and PEP in the first minute of the post-task instruction phase[2], consistent with previous research (e.g., Chalabaev, Major, Cury, & Sarrazin, 2009). For HR, there was a significant increase, $t(45) = 4.41$, $p < .001$, $d = .17$, from the fifth minute (M = 66.30bpm, SD = 16.34bpm) of baseline to the first minute (M = 69.09bpm, SD = 17.20bpm) of the post-task instruction phase. For PEP, there was a significant attenuation, $t(43) = 5.71$, $p < .001$, $d = .23$, from the fifth minute (M = 136.86ms, SD = 13.72ms) of baseline to the first minute (M = 133.73ms, SD = 13.64ms) of the post-task instruction phase. HR and PEP reactivity indicated that participants engaged with the task. In addition, participants indicated that task success ($M = 3.63$, $SD = .14$) was important to them, $t(42) = 26.42$, $p < .001$. Task importance did not differ $t(41) =.39$, $p > .05$, between challenge and threat conditions.

4.2. Cardiovascular reactivity between conditions

The CV reactivity between conditions is shown in Figure 1. Independent *t*-tests showed that participants in the challenge condition ($M = -8.67$, $SD = 40.76$) displayed significantly lower TPR[3] reactivity $t(42) = 4.54$, $p < .001$, $d = 1.37$, than participants in the threat condition ($M = 47.88$, $SD = 41.68$). In addition, participants in the challenge condition

(M = .18, SD = .20) displayed significantly higher CO[4] reactivity $t(41) = 4.58$, $p < .001$, d = 1.42, than participants in the threat condition (M = -.09, SD = .18).

4.3. Performance

Bean bag throwing performance was better in the challenge condition (M = 94.57, SD = 17.39) than the threat condition (M = 85.65, SD = 17.99) and approached significance at the .05 level $t(44) = 1.71$, p = .08, in performance scores between conditions, such that performance was better in the challenge condition (M = 94.57, SD = 17.39) than the threat condition (M = 85.65, SD = 17.99).

4.4. Psychological components of the TCTSA

The means of the self-reported psychological states are shown in table 1. There were no significant differences for self-reported psychological states[5] between challenge and threat conditions.

5. Discussion

The results of Study 1 showed that challenge and threat instructions led to CV reactivity indicative of challenge and threat states respectively. Further, those receiving challenge instructions performed better in the bean bag throwing task as hypothesised, although this finding only approached significance at the 0.05 level it is consistent with previous research that CV reactivity consistent with challenge is related to superior motor performance (e.g. Blascovich et al., 2004; Moore et al., 2012; Turner et al., 2012; 2013). This is the first study to show that it is possible to manipulate CV reactivity using task instructions based on the resource appraisals only, and that this manipulation may influence motor task performance. This further extends previous research by making task instructions more analogous between conditions than in previous research (e.g., Atler et al., 2010; Feinberg & Aiello, 2010; Hemenover & Dienstbier, 1996; Taylor & Scogin, 1992; Tomaka et al., 1997). Indeed, there were no differences in self-reported task importance between conditions.

No differences were found in self-report measures between the groups. This is contrary to some past research where cognitive appraisals (Tomaka et al., 1997) and emotions (Moore et al., 2012) differed between challenge and threat conditions. However, the results from Study 1 are consistent with previous research which has shown that self-reported resource appraisals do not correlate with challenge and threat CV reactivity in the manner predicted by the TCTSA (Meijen et al., 2013; Turner et al., 2012; 2013). This finding is also consistent with broader evidence that self-reports may not always relate to physiological reactivity (e.g., Martinek et al., 2003).

Although the bean-bag throwing task yielded task engagement and self-reported perceptions of task importance, the lack of ecological validity inherent in the throwing task may have limited task importance. To address this, in Study 2 we examined if similar task instructions could manipulate challenge and threat states with regard to a more meaningful task (i.e., a task that has implications for actual physical harm). Study 2 had similar experimental and analytical strategies, but it differed in three main ways. First, task instructions were related to a physically demanding climbing task and second, we added measures to assess participants' thoughts immediately after receiving task instructions, recorded qualitatively via self-report to indicate engagement in the task during mental preparation. Third, instead of a performance score we used a behavioural indicator of performance, that being attendance at the climbing task. A challenge state is proposed to be associated with approach motivation, while threat is associated with an avoidance approach and a general orientation away from the stimulus (Jones et al., 2009). In line with the TCTSA, we hypothesised that significantly more participants receiving the challenge instructions would attempt the climbing task.

6. Study 2

7. Methods

7.1. Participants

Forty six (*Female* = 9, *Male* = 41) UK University undergraduate students (*M*age = 21.02years, *SD*age = 2.46years) were randomly and unknowingly allocated to either a challenge (*N* = 24; *Female* = 5, *Male* = 19) or threat (*N* = 22; *Female* = 3, *Male* = 19) task video condition[6]; all participants were normotensive and reported being in good health. Novice climbers[7] were recruited as climbing experience is a determinant of climbing stress and anxiety (Hardy & Hutchinson, 2007; Janot et al., 2000). Ethical approval was granted from the University and informed consent was obtained prior to data collection. Participants received course credit.

7.2. Measures

The CV measures were recorded in the same way as in study 1. So too were emotions (Cronbachs Alpha: anxiety = .92, excitement = .85, happiness = .93), achievement goals (Cronbachs Alpha: MAp = .81[8], MAv = .87, PAp = .93, PAv = .91), and task importance, but with reference to the climbing task. In addition, a single-item was added to the SEQ in which participants were asked to indicate how helpful they perceived their overall emotional state to be on a 5-point Likert-scale ranging from 0 (*Not at all*) to 4 (*Extremely*).

7.2.1. Self-efficacy

Participants were asked “With reference to the upcoming climbing performance, to what extent do you feel confident that you can climb effectively in the upcoming climbing task?” Responses were recorded on a 9-point Likert-scale ranging from 1 (*Not at all*) to 9 (*Completely*).

7.2.2. Perceived control

Participants completed one item in relation to the climbing task, adapted from the Academic Control Scale (Perry, Hladkyj, Pekrun, & Pelletier, 2001). Participants were asked “to what extent do you feel that you have control over the factors that will determine your climbing performance?" Responses were recorded on a 7-point Likert-scale ranging from 1 (*No control*) to 7 (*Total control*).

7.2.3. Cognitive appraisal

Participants were asked "Overall, how do you feel about your upcoming Climbing Task performance?" Responses were recorded on a 9-point Likert-scale ranging from -4 (*Threatened*) to +4 (*Challenged*).

7.2.4. Thoughts about the climbing task

To confirm that participants used the two minutes of mental preparation to engage in task-relevant thoughts, participants were asked to write down what they were thinking in the two minutes immediately after CV data collection.

7.2.5. Climbing task performance

The climbing task required participants to ascend a 10-meter climbing wall located in the university sports hall. A climbing instructor set-up an F2 sport climbing route for the task (strictly vertical, 3 meters wide, and a moderate difficulty level). Participants were given five-minutes to climb the wall and could stop climbing at any point. If participants came detached from foot and hand holds, the instructor supported their weight while they decided whether to continue the climb or not. If after five minutes a participant had not completed the climb, they were asked to stop climbing.

7.3. Procedures

Laboratory and participant preparation followed the same procedures as in Study 1, but in Study 2 participants were informed that they would watch a short video on a laptop computer accompanied by a set of audio instructions in which key phrases were reinforced in text on the screen.

7.3.1. Cardiovascular and psychological data collection

CV data followed the same protocol as in Study 1, but in Study 2 participants watched one of two videos about an upcoming climbing task, depending on whether they were allocated to the challenge or threat condition (both videos available on request from the first author). The videos lasted for one minute and were designed to induce either challenge or threat in a similar way to the instructions in Study 1. Both videos contained the same visual footage of the climbing wall from a first-person perspective and multiple angles below, on, and above the wall, but different audio instructions. Instructions in the challenge video promoted resource appraisals of high self-efficacy ("you can feel confident that you will be able to climb effectively"), high perceived control (you have control over the skills required to climb well"), and a focus on approach goals ("try your best to stay on the wall and get as high as you can"). The threat video promoted resource appraisals of low self-efficacy ("you obviously can't be sure that you will climb the wall effectively"), low perceived control ("how well you do on the task may be related to factors outside of your control"), and a focus on avoidance goals ("try your best not to fall off the wall at any point"). In addition both sets of instructions informed participants that they had five minutes to complete the climbing task, that they would be given climbing guidance, and that their climb would be video recorded and later viewed so climbing ability could be assessed. Importantly, while CV data were collected participants were told that they would be escorted to the climbing wall immediately after data collection had ceased. This was to ensure that CV and self-report measures reflected participants' responses to approaching an imminent climbing task, even though the climbing session was to be arranged for a different day. The final part of the videos instructed participants to mentally prepare for the climbing task for two minutes by thinking about performing the climb. To be clear, there was one minute of task instructions and the two minutes of mental preparation (three minutes in total), in which CV data were recorded throughout. After the two minutes of mental preparation had lapsed participants completed the self-report measures in relation to the upcoming climbing task. Then, participants were informed that they would not be climbing at that moment in time and to indicate the climbing session that they could attend from the options available. Participants were given a choice of four climbing sessions to attend, each on a different day across four weeks at 9:00am. At this point, four participants indicated that they could not attend any of the sessions due to academic timetable clashes. All other participants agreed to attend one of the sessions and were given an information sheet detailing that they were in no way obligated to climb. Participants received no inducement and were not contacted prior to their climb, as we did not want to coerce participants into attending. After indicating a climbing session the CV recording equipment were removed from participants, after which they were briefed about the climbing task (no obligation to attend and safety information) before departing.

7.3.2. Climbing task

Eighteen participants attended the climbing task in total. On arrival to the sports hall for the climbing task, participants were given climbing instructions by a qualified (Single Pitch Award) climbing instructor (Chairman of University Mountaineering Club) who was blind to the instructions participants had received. The guidance provided by the instructor was identical for both conditions and included safety information, demystification of the climbing equipment, and simple advice such as “use your legs to push up rather than your arms to pull up” to avoid injury. Participants were then fastened to a climbing harness and attached to a safety rope so the instructor could belay the participants up (and down) the wall. Participants were then reminded that they had five minutes to climb and could cease climbing at any point. After being lowered to the ground, participants were released from the safety rope and harness, and were provided with a full debrief about the study.

8. Analytic Strategy

The analytic strategy followed that used in Study 1 apart from one additional step. To examine the frequency of participants attending the climbing session in each condition, a chi-square test for independence was carried out. Independent *t*-tests also examined differences in CV reactivity between attendees and non-attendees. All multicollinearity, normality and outlier checks met the assumptions necessary for all data analysis.

9. Results

9.1. Task engagement

Two separate paired samples *t*-tests were conducted and Cohen's *d* (Cohen, 1992) calculated to compare the fifth minute of baseline HR and PEP with HR and PEP with the first minute of the post-task instruction phase for all participants [9,10]. For HR, there was a significant increase, $t(43) = 2.85$, $p < .01$, $d = .21$, from the fifth minute ($M = 67.73$bpm, $SD = 9.95$bpm) of baseline to the first minute ($M = 69.93$bpm, $SD = 11.36$bpm) of the post-task instruction phase. For PEP, there was a significant attenuation, $t(43) = 4.95$, $p < .001$, $d = .24$, from the fifth minute ($M = 128.09$ms, $SD = 14.42$ms) of baseline to the first minute ($M = 124.64$ms, $SD = 14.36$ms) of the post-task instruction phase. HR and PEP reactivity indicated that participants engaged with climbing task (e.g., Blascovich et al., 2011). In addition, participants indicated that task success was important ($M = 5.80$, $SD = 1.34$) to them, $t(45) = 29.30$, $p < .001$. Task importance did not differ, $t(44) = .42$, $p > .05$, between challenge and threat conditions.

9.2. Cardiovascular reactivity between conditions

Independent *t*-tests and inspection of mean values (see Figure 2) showed that participants in the challenge condition ($M = -9.80$, $SD = 39.95$) displayed significantly lower TPR reactivity, $t(44) = 2.60$, $p < .02$, $d = .76$, than participants in the threat condition ($M = 24.44$, $SD = 49.18$). In addition, participants in the challenge condition ($M = .22$, $SD = .19$)

displayed significantly higher CO reactivity, $t(44) = 3.39$, $p < .01$, $d = .99$, than participants in the threat condition ($M = -.09$, $SD = .40$).

9.3. Psychological and behavioral components of the TCTSA

The means of the self-reported psychological states are shown in table 1. There were no significant differences for self-reported psychological states between challenge and threat conditions[11]. Attendance data were coded into two groups: attendees ($N = 18$), and non-attendees ($N = 38$). A Chi-square test for independence indicated no significant association between condition and attendance, χ^2 (1, 46) = 1.30, $p > .05$, *phi* = .17. Inspection of the cross-tabulation revealed that of the 18 participants that attended the climb, 61.1% were in the challenge condition ($N = 11$) and 39.9% were in the threat condition ($N = 7$). In addition, an independent *t*-test was conducted to examine differences in CV reactivity between those that attended and those that did not. There was no significant difference in TPR reactivity, $t(44) = .65$, $p > .05$, between attendees ($M = .88$, $SD = 45.48$) and non-attendees ($M = 10.24$, $SD = 49.01$). There was no significant difference in CO reactivity, $t(44) = 1.18$, $p > .05$, between attendees ($M = .15$, $SD = .35$) and non-attendees ($M = .03$, $SD = .34$).

10. Discussion

The results from Study 2 show that challenge and threat instructions led to CV reactivity indicative of challenge and threat respectively. The findings of Study 2 support Study 1 by showing that it is possible to manipulate CV reactivity using task instructions varying only the resource appraisals without altering the task demands between challenge and threat conditions. As in Study 1, self-reported task importance did not differ between conditions. In addition, as in Study 1 no differences were found in self-report measures between the groups contrary to some past research (e.g., Moore et al., 2012; Tomaka et al., 1997) but consistent with research examining the TCTSA (Meijen et al., 2013; Turner et al., 2012; 2013). Again, this finding is consistent with broader evidence that self-reports may not always relate to physiological reactivity (e.g., Martinek et al., 2003). The delay between CV recording and climbing performance meant that a performance measure was not appropriate, so instead, in Study 2 we assessed behaviour by recording attendance at the climbing task. Although the majority of participants who attended were in the challenge group this difference was not significant, and because less than half the participants we collected data from attended, this analysis is underpowered to detect what may be meaningful differences in behaviour. Study 2 extended Study 1 by adopting a physically demanding task with the potential for physical harm, and by using video instructions.

11. General Discussion

Collectively, the results from Studies 1 and 2 partially support the theoretical components of the TCTSA and offer a methodological advancement for the manipulation of challenge and threat states and add to the extant literature by demonstrating that challenge and threat CV reactivity can be manipulated using only the resource appraisals. In both studies, self-reported task importance did not differ between conditions. Specifically, challenge instructions that only promoted high self-efficacy, high perceived control, and approach goals led to challenge CV reactivity. Threat instructions that only promoted low self-efficacy, low perceived control, and avoidance goals led to threat CV reactivity. These are the first studies to show that challenge CV reactivity can be promoted by task instructions without devaluing the perceived task demands of the motivated performance situation. In addition, in Study 1 those who received challenge instructions performance better in the motor task than those who received threat task instructions, and in Study 2 those who attended the climb displayed greater challenge reactivity than those did not attend, although neither difference was significant. Notably, there were no differences in self-reported resource appraisals (self-efficacy, control, and achievement goals) between challenge and threat instruction conditions, supporting research that indicates that self-reports and physiological reactivity often are unrelated.

The present paper supports previous studies indicating that challenge and threat CV reactivity can be manipulated using instructional sets, and extends previous research (e.g., Tomaka et al., 1997) by manipulating challenge and threat CV reactivity using task instructions that focus only on the resource appraisals as proposed in the TCTSA (Jones et al., 2009). In addition, findings from Study 1 provides some qualified support for the growing literature that asserts the association between challenge and superior motor performance (e.g., Moore et al., 2012; Turner et al., 2012; 2013). Hence, the present paper supports the theoretical components of the TCTSA (Jones et al., 2009) and offers further validation for the challenge and threat CV reactivity patterns in the BPS model (Blascovich & Mendes, 2000).

The main aim of this paper was to manipulate challenge and threat CV reactivity using the TCTSA as a framework, thus it was hypothesised that by emphasising the demands in both conditions and varying the resource appraisals between conditions, corresponding differences in CV reactivity and performance between conditions would emerge. In contrast to previous studies that have manipulated challenge and threat (e.g., Moore et al., 2012; Tomaka et al., 1997) no changes in self-report measures were observed. Counter intuitive, or counter theoretical, self-report results are consistent with previous challenge and threat research (e.g., Meijen et al., 2013; Mendes, Major, McCoy, & Blascovich, 2008; Turner et al., 2012; 2013) and there a two potential reasons for the lack of self-report findings documented in this paper and in past research. First, participants may have provided biased responses to questionnaires across the two studies due to reasons of self-presentation (e.g., Paunonen & LeBel, 2012), whereby individuals may consciously engage in a deliberate strategy of misrepresentation to make a good impression, or may misrepresent unconsciously, motivated by an implicit need for self-enhancement and ego maintenance (e.g., Paunonen &

LeBel, 2012). Blascovich and Mendes (2000) suggested that one of the contributing factors dictating whether individuals can articulate their appraisals is the extent to which self-presentation concerns predominate. In other words, and in the context of motivated performance, if individuals wish to present themselves as capable of succeeding in a given task, they may report thinking and feeling in ways that indicate their coping potential, regardless of whether they actually harbour these psychological states (Wiechman, Smith, Smoll, & Ptacek, 2000). In sum, self-report measures have long been criticised for their susceptibility to response distortion (e.g., Paunonen & LeBel, 2012) and the lack of self-report findings amongst such convincing CV findings in this paper may be symptomatic of the use of easily biased self-report questionnaire items.

Second, self-report measures requiring introspection into the appraisal mechanisms driving CV reactivity to a stressor may be a poor window into processes that occur unconsciously (e.g., Frijda, 1993; LeDoux, 1998; Quigley et al, 2002). Research recognises that self-reported stress levels may be unrelated to physiological responses (e.g., Martinek et al., 2003). Further, Blascovich and Mendes (2000) in a modification of the BPS model recognise that individuals “may make non-conscious demand or resource appraisals, or both, arriving at a state of challenge or threat without any awareness of the appraisals themselves” (p. 64). In effect, neither demand nor resource appraisals need be conscious, and it is also possible that appraisals that are conscious can be made without the individual being aware that they are engaging in the appraisal process (Blascovich & Mendes, 2000; Lovallo, 2005).

LeDoux (1998) suggests that appraisal can occur in the absence of areas of the brain important for conscious processing. This rapid appraisal mechanism is likely to occur in motivated performance situations where there is a potential for physical and or psychological (esteem) harm. LeDoux attributes the appraisal process to the amygdala, which is critically involved in the activation of the pituitary and adrenal glands, involved in the bodily responses to stress included in challenge and threat reactivity. During this process, conscious awareness of the stimulus and conscious control of physiological responses are not required, so introspection won't be possible. Further, even if an individual does have introspective access, the conscious content is not likely to be what triggered the emotional response.

Finally, Blascovich and Mendes (2000) asserted that the CV patterns of challenge and threat offer unambiguous and less error prone evidence of challenge and threat states. Taken into consideration alongside the unconscious process outlined by LeDoux, and the many criticisms by preeminent appraisal researchers such as Zajonc, and Ekman of introspective methods, perhaps we should rely more on techniques that do not depend on verbal reports (Scherer, 1993). In sum, introspective self-reports concerning appraisal, such as those used in this paper to measure resource appraisals, have obvious drawbacks that have been highlighted many times particularly in criticisms of cognitive appraisal research (e.g., Ellsworth & Scherer, 2003; Fridja, 1993; LeDoux, 1998; Parkinson, 1996). Future researchers are challenged to find inventories that can overcome the self-presentational tendencies of research participants, such as vocalisation as advocated by Weisbuch et al. (2009), as it is possible that challenge and threat states are more difficult, or potentially impossible, to accurately assess via self-report measures (Chalabaev et al., 2009).

It is also possible that in the present paper the instructions influenced appraisals not immediately accessible to the participants. Indeed, it may be that only some aspects of cognitive appraisal are consciously accessible with an even smaller subset of those perceptions deemed acceptable to report by the individual (e.g., Blascovich & Mendes, 2000; Greenwald & Banaji, 1995; LeDoux, 1998; Quigley, Barrett, & Weinstein, 2002). Further, there is evidence that the subconscious awareness of evocative stimuli can determine CV responses, bypassing measurable cognitive appraisal (e.g., Weisbuch-Remington, Mendes, Seery, & Blascovich, 2005), and that self-reported stress levels may be unrelated to physiological responses (e.g., Martinek et al., 2003).

The key findings from the present paper have implications for stress management in motivated performance settings. Importantly the present paper shows that a challenge state can be promoted without altering the perceived demands of an upcoming task. This finding is valuable because influencing the perceived demands of a task in actual performance settings may be difficult. For example, convincing a student approaching a final examination that they have studied hard for and will determine their eligibility for college that it does not require effort, has no danger for esteem (e.g., is not important) and for which the result is certain, is unrealistic and unnecessary. In contrast, convincing them that they have the skills to succeed, have control over their performance, while encouraging them to focus on success, may be more plausible to some. In sum, based on the studies reported in the present paper, and previous research, challenge framed instructions could promote stress management and facilitate performance.

By addressing the limitations in the present paper, the findings from the two studies would be strengthened. Of particular note, it is not possible to distinguish whether all three resource appraisals were manipulated successfully, and if they were, which resource appraisal caused the observed changes in CV reactivity. The TCTSA posits that all three resource appraisals are necessary for a challenge state, but further research could manipulated each resource appraisal separately to explore this avenue. The current paper explored the additive effects of the resource appraisals on CV reactivity. It is possible, that rather than altering resource appraisals subtle differences in semantics between conditions may have presented the tasks more positively in the challenge condition than in the threat condition. To explain, even though the instructions were more analogous between challenge and threat conditions compared to past research, words like “can” and “have” were used in the challenge instructions, whereas “can’t”, “may be”, and “not” were used in the threat instructions. Therefore, it is possible that the use of concomitant verbs contributed to the exhibition of challenge and threat CV reactivity in the present study. Further, to understand the relationships between CV reactivity, psychological, and performance variables, the use of regression analyses are required, for which a larger participant sample is needed. Also, the situations created in both studies represent artificial circumstances made meaningful by creating a competition (as in Study 1) and using a physically demanding task (as in Study 2). Therefore, how individuals respond in real-life situations, which are more self-relevant, and further how instructions could alter these responses, is not yet known. In addition, while this paper maintained perceived task demands between instructions thus building on past research, Tomaka et al. (1997) report greater increases in HR and greater decreases in PEP than shown in the current paper. This could suggest that participants in Tomaka et al’s study were more engaged in the task than participants in the current paper. Alternatively, the presence of a surveillance camera during CV data collection in Tomaka et al’s study may have added additional evaluative task demands that can elevate HR and attenuate PEP (Blascovich, Mendes, Hunter, & Salomon, 1999).

The findings within this paper, along with findings from previous research, present a number of potentially fruitful avenues of future research. For example, although the instructions used in the current paper were more analogous between challenge and threat conditions than instructions used in previous research (e.g., Feinberg & Aiello, 2010), the slight variation in semantics could be addressed by developing instructions that are semantically identical, while still manipulating the resource appraisals.

We chose to use the BPS model and the TCTSA as frameworks for this paper, as they offer testable approaches to understanding how individuals respond in motivated performance situations. One other approach that may offer a complimentary explanation of our findings is

Wright's (1998) ability extension of Brehm's (Brehm & Self, 1989) motivational intensity theory. The ability extension suggests that in people who consider themselves incapable of success in a given motivated performance situation where task characteristics are constant, demand appraisals should be greater than when they consider themselves capable. Therefore, low ability people who perceive the task as too difficult may evidence less sympathetic CV responsiveness than high ability people approaching a task of the same difficulty (Wright, Martin, & Bland, 2003). This approach relates to the self-efficacy and perceived control aspects of the resource appraisals. For example, it may be that an individual who does not believe they have the skills to succeed and who perceives the task requirements as beyond their control may not engage in the task and therefore not exhibit significant CV engagement (e.g., increased HR and attenuated PEP from base levels). Further, although the BPS model and the TCTSA suggest that endocrinal mechanisms cause different CO and TPR reactivity in challenge and threat states, there are alternative explanations. For example, when approaching a motivated performance situation increased muscular tension, as part of an anxiety response, may inhibit vessel dilation and thus increasing TPR (Wright & Kirby, 2003). We encourage future research to also adopt Wright's ideas when exploring CV reactivity in motivated performance situations.

To conclude, these are the first studies to show that challenge CV reactivity can be promoted via task instructions developed using the resource appraisals from the TCTSA. Future research should employ repeated measures methods in order to examine the within participant effects of using challenge and threat task instructions to elicit challenge and threat states (e.g., Quigley et al, 2002). The present paper has implications for the management of psychophysiological responses to motivated performance situations through the use of task instructions which promote the self-efficacy, perceived control, and a focus on approach goals.

References

Baker, J., Cote, J., Hawes, R. 2000. The relationship between coaching behaviours and sport anxiety in athletes. J. Sci. Med. Sport 3, 2, 110-119.

Bandura, A., 2006. Guide for constructing self-efficacy scales. In: Pajares, F., Urdan, T. (Eds.). Self-efficacy beliefs of adolescents, Vol. 5, Information Age Publishing, Greenwich, CT, pp. 307-337.

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

Blascovich, J., Mendes, W. B., Hunter, S. B., Salomon, K., 1999. Social "facilitation" as challenge and threat. J. Pers. Soc. Psychol 77, 68-77. doi: 10.1037/0022-3514.77.1.68

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

Blascovich, J., Seery, M. D., Mugridge, C. A,. Norris, K., Weisbuch, M., 2004. Predicting athletic performance from cardiovascular indexes of challenge and threat. J. Exp. Soc. Psychol 40, 683-688. doi: 10.1016/j.jesp.2003.10.007

Brehm, J. W., Self, E. 1989. The intensity of motivation. In: Rozenweig, M. R., Porter, L. W. (Eds.), Annual review of psychology, Palo Alto: Annual Reviews, pp. 109-131

Chalabaev, A., Major, B., Cury, F., Sarrazin, P., 2009. Physiological markers of challenge and threat mediate the effects of performance-based goals on performance. J. Exp. Soc. Psychol 45, 991-994. doi: 10.1016/j.jesp.2009.04.009

Cohen, J., 1992. A power primer. Psychol. Bull 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. J. Sport Exercise Psy 25, 4, 456-476.

Dienstbier, R. A., 1989. Arousal and physiological toughness: Implications for mental and physical health. Psychol. Rev 96, 84-100. doi: 10.1037/0033-295X.96.1.84

Dienstbier, R. A. 1992. Mutual impacts of toughening on crises and losses. Faculty Publications: Department of Psychology, University of Nebraska-Lincoln.

Eysenck, M. W., Calvo, M. G. 1992. Anxiety and performance: the processing efficiency theory. Cognition Emotion 6, 409–434.

Feinberg, J. M., Aiello, J. R. 2010. The effect of challenge and threat appraisals under evaluative presence. J. Appl. Soc. Psychol 40, 8, 2071–2104. doi: 10.1111/j.1559-1816.2010.00651.x

Greenwald, A. G., Banaji, M. R. 1995. Implicit social cognition: Attitudes, self-esteem, and stereotypes. Psychol. Rev 102, 4-27.

Hardy, L., Hutchinson, A. 2007. Effects of performance anxiety on effort and performance in rock climbing: A test of processing efficiency theory. Anxiety Stress. Copin 20, 147-161. doi:10.1080/10615800701217035

Hemenover, S. H., Dienstbier, R. A. 1996. The effects of an appraisal manipulation: Affect, intrusive cognition, and performance for two cognitive tasks. Faculty Publications, Department of Psychology Press 113, 319-340.

Holmes, D. S., Houston, B. K. 1974. Effectiveness of situation redefinition and affective isolation for reducing stress. J. Pers. Soc. Psychol 29, 212-218.

Jamieson, J. P., Koslov, K., Nock, M. K., Mendes, W. B. 2012. Experiencing discrimination increases risk-taking. Psychol. Sci X, 1-9 doi: 10.1177/0956797612448194

Janot, J. M., Steffen, J. P., Porcari, J. P., Maher, M. A. 2000. Heart rate response and perceived exertion for beginner and recreational sport climbers during indoor climbing. J. Exerc. Physiol 3, 1, 1-7.

Jones, M.V, Lane, A.M., Bray, S., Uphill, M.A., Caitlin, J., 2005. Development and validation of the Sport Emotions Questionnaire. J. Sport Exercise. Psych 27, 407-431.

Jones, M. V., Mace, R. D., Bray, S. R., MacRae, A., Stockbridge, C. 2002. The impact of motivational imagery on the emotional state and self-efficacy levels of novice climbers. J. Sport Behav 25*,* 57-73.

Jones, M., Meijen, C., McCarthy, P. J., Sheffield, D., 2009. A theory of challenge and threat states in athletes. Int. Rev. Sport Exerc. Psychol 2, 161-180. doi: 10.1080/17509840902829331

Koriat, A., Melkman, R., Averill, J. R., Lazarus, R. S. 1971. The self-control of emotional reactions to a stressful film. J. Pers 40, 601-619.

Lazarus, R. S. 1991. Cognition and motivation in emotion. Am. Psychol 46, 352-367.

Lazarus, R. S., Folkman, S., 1984. Stress, appraisal, and coping. Springer, New York.

LeDoux, J. 1998. The emotional brain. London: Phoenix.

Martinek, L., Oberascher-Holzinger, K., Weishuhn, S., Klimesch, W., Kerschbaum, H. H., 2003. Anticipated academic examinations induce distinct cortisol responses in adolescent pupils. Neuroendocrinol. Lett 6, 24, 449-453.

Meijen, C., Jones, M.V., Sheffield, D., McCarthy, P. J. 2013. Challenge and threat states: Cardiovascular, affective, and cognitive responses to a sports-related speech task. Motiv. Emotion. DOI: 10.1007/s11031-013-9370-5

Mendes, W. B., Major, B., McCoy, S., Blascovich, J., 2008. How attributional ambiguity shapes physiological and emotional responses to social rejection and acceptance. J. Pers. Soc. Psychol 94, 2, 278-91. doi: 10.1037/0022-3514.94.2.278

Mendes, W. B., Reis, H. T., Seery, M. D., Blascovich, J., 2003. Cardiovascular correlates of emotional expression and suppression: Do content and gender context matter? J. Pers. Soc. Psychol 84, 771-792. doi: 10.1037/0022-3514.84.4.771

Moore, L. J., Vine, S. J., Wilson, M. R. 2012. The effect of challenge and threat states on performance: An examination of potential mechanisms. Psychophysiology 49, 10, 1417-25. doi: 10.1111/j.1469-8986.2012.01449.x

Muis, K. R., Winne, P. H. 2012. Assessing the psychometric properties of the achievement goals questionnaire across task contexts. Can. J. Edu 35, 2, 232-248.

Nisbett, R. E., Schachter, S. 1966. Cognitive manipulation of pain. J. Exp. Soc. Psychol 2, 227–236.

Paunonen, S. V. LeBel, E. P. 2012. Socially desirable responding and its elusive effects on the validity of personality assessments. J. Pers. Soc. Psychol103, 1, 158-175.

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. J. Educ. Psychol 93, 4, 776-789. doi: 10.1037/0022-0663.93.4.776

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.

Schneider, T.R., 2008. Evaluations of stressful transactions: what's in an appraisal? Stress Health 24, 2, 151–158. doi: 10.1002/smi.1176

Seery, M. D., 2011. Challenge or threat? Cardiovascular indexes of resilience and vulnerability to potential stress in humans. Neurosci. Biobehav. R 35, 1603–1610. doi: 10.1016/j.neubiorev.2011.03.003

Seery, M. D., Blascovich, J., Weisbuch, M., Vick, S. B., 2004. The relationship between self-esteem level, self-esteem stability, and cardiovascular reactions to performance feedback. J. Pers. Soc. Psychol 87, 133-145. doi: 10.1037/0022-3514.87.1.133

Seery, M. D., Weisbuch, M., Blascovich, J., 2009. Something to gain, something to lose: The cardiovascular consequences of outcome framing. Int. J. Psychophysiol 73, 308-312. doi: 10.1016/j.ijpsycho.2009.05.006

Seery, M. D., Weisbuch, M., Hetenyi., M. A., Blascovich, J., 2010. Cardiovascular measures independently predict performance in a university course. Psychophysiology 47, 535-539. doi: 10.1111/j.1469-8986.2009.00945.x

Seery, M. D., West, T. V., Weisbuch, M., Blascovich, J., 2008. The effects of negative reflection for defensive pessimists: Dissipation or harnessing of threat? Pers. Indiv. Differ 45, 515-520. doi: 10.1016/j.paid.2008.06.004

Sherwood, A., 1993. Use of impedance cardiography in cardiovascular reactivity research. In: Blascovich, J., Katkin, E.S. (Eds.), Cardiovascular Reactivity to Psychological Stress and Disease, American Psychological Association, Washington, DC, pp. 157–199.

Smith, R. E., Smoll, F. L., Weichman, S. A. 1998. Measurement of trait anxiety in sport. In: Duda, J. L. (Ed.), Advances in sport and exercise psychology measurement. Fitness Information Technology, Inc, The University of Michigan, pp. 105-128

Speisman, J. C., Lazarus, R. S., Davison, L. A., Mardkott, A. M. 1964. Experimental analysis of a film used as a threatening stimulus. J. Consult. Psychol 28, 23-33.

Taylor, C. J., Scogin, F. 1992. Dysphoria and coping in women: The effects of threat and challenge appraisals. J. Soc. Clin. Psychol 11, 26-42.

Tomaka, J., Blascovich, J., Kibler, J., Ernst, J. M., 1997. Cognitive and physiological antecedents of threat and challenge appraisal. J. Pers. Soc. Psychol 73, 1, 63-72. doi: 10.1037/0022-3514.73.1.63

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. Int. J. Psychophysiol 86, 1, 48-57. doi:10.1016/j.ijpsycho.2012.08.004

Turner, M. J., Jones, M. V., Sheffield, D., Slater, M. J., Barker, J. B., Bell, J. 2013. Who thrives under pressure? Predicting the performance of elite academy cricketers using the cardiovascular indicators of challenge and threat states. J. Sport Exerc. Psychol 35, 4, 387-397.

Vargas-Tonsing, T.M. 2009. The effects of coaches' pre-game speeches on athletes' perceptions of self-efficacy and emotion. J. Sport Behav 32, 92-111.

Weisbuch-Remington, M., Mendes, W. B., Seery, M. D., Blascovich, J., 2005. The nonconscious influence of religious symbols in motivated performance situations. Pers. Soc. Psychol. B 31, 1203-1216. doi: 10.1177/0146167205274448

Wright, R. A. 1998. Ability perception and cardiovascular response to behavioral challenge. In: Kofka, M., Weary, G., Sedek, G. (Eds.), Personal control in action: Cognitive and motivational mechanisms. New York: Guilford, pp. 197-232.

Wright, R. A., Martin, R. E., Bland, J. L. 2003. Energy resource depletion, task difficulty, and cardiovascular response to a mental arithmetic challenge. Psychophysiology 40, 98-105.

Wright, R. A., Kirby, L. D. 2003. Cardiovascular correlates of challenge and threat appraisals: A critical examination of the biopsychosocial analysis. Pers. Soc. Psychol. Rev 7, 216-233.

Footnotes

[1] Further to this, data from six participants (*female* = 3, *male* = 3) were excluded from the study, three due to poor quality impedance data, and three due to equipment failure during data collection. Exclusion of data due to equipment failure and poor signal is not uncommon when using impedance cardiography (see Seery, Weisbuch, Hetenyi, & Blascovich, 2010).

[2] PEP data from two participants were excluded from further analyses as they were identified as significant outliers.

[3] TPR data from two participants were excluded from further analyses as they were identified as significant outliers.

[4] CO data from five participants were excluded from further analyses as they were identified as significant outliers.

[5] Self-report data identified as significant outliers were excluded from further analyses including anxiety (*N* = 3), control (*N* = 2), appraisal (*N* = 4), and task importance (*N* = 3).

[6] Further to this, data from four participants (*female* = 1, *male* = 3) was excluded from the study, one due to poor quality impedance data, and three due to experimenter error during data collection

[7] One participant indicated a moderate level of climbing experience and climbs four times a year. Therefore all analyses were performed twice; once with this participant excluded and once with this participant included. The exclusion of this participant did not alter the results of the data analysis markedly.

[8] For MAp, Cronbachs' alpha was .49 so one item was removed. The removed item did not correlate well with the other two items for this subscale (*r* = .03).

[9] HR data from two participants were excluded from further analyses as they were identified as significant outliers.

[10] PEP data from two participants were excluded from further analyses as they were identified as significant outliers.

[11] Self-report data identified as significant outliers were excluded from further analyses including control (*N* = 2), and helpfulness of emotional state (*N* = 2).