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The relationship between challenge and threat states and anaerobic power, core affect, perceived exertion, and self-focused attention during a competitive sprint cycling task

Abstract

This study investigated the relationship between challenge and threat states and anaerobic power, core affect, perceived exertion, and self-focused attention during a competitive sprint cycling task. Thirty-five participants completed familiarization, baseline, and pressurized Wingate tests. Before the pressurized test, challenge and threat states were measured via self-report (demand resource evaluation score) and cardiovascular reactivity (challenge/threat index). After the pressurized test, relative peak power, core affect, perceived exertion, and self-focused attention were assessed. Evaluating the pressurized test as more of a challenge (coping resources match or exceed task demands) was associated with greater increases in relative peak power (versus the baseline test), more positive affect, lower perceived exertion, and less self-focused attention. However, challenge/threat index failed to predict any variable. While the findings raise questions about the value of the physiological pattern underlying a challenge state for anaerobic power, they highlight the benefits of evaluating a physically-demanding task as a challenge.

Keywords: Stress; demand and resource evaluations; cognitive appraisals; cardiovascular reactivity; sports performance

Introduction

"Every professional bike rider trains his legs, but very few train their minds, the only muscle they use to make decisions in races" (Cavendish, 2014, p. 4)

As illustrated by the above quote from multiple Tour de France stage winner Mark Cavendish, psychology plays a key role in competitive sprint cycling and yet is often omitted from the training programs of elite cyclists. Indeed, despite extensive research into the physiological demands of sprint cycling (e.g., Menaspa et al., 2015), relatively little research has investigated the psychological factors associated with sprint cycling performance. To address this gap in the literature, the present study offered an initial test of the relationship between pre-competition psychophysiological responses to stress and sprint cycling performance in a laboratory setting, using the biopsychosocial model (BPSM) of challenge and threat states as a theoretical framework (Blascovich & Tomaka, 1996).

The BPSM was developed to highlight the connection between the brain (i.e., psychological processes) and body (i.e., physiological responses) during potentially stressful situations (Blascovich, 2008). Grounded in the work of Lazarus and Folkman (1984) and Dienstbier (1989), the BPSM proposes that during a motivated performance situation (e.g., exam, speech, sporting competition), an individual's physiological reaction to stress is influenced by their evaluation of situational demands and personal coping resources (Blascovich, 2008). Individuals who believe that they have sufficient resources to cope with the demands of the situation, evaluate it as a challenge. Conversely, individuals who judge that they lack the necessary coping resources, evaluate it as a threat (Seery, 2011). Importantly, these evaluations only occur when an individual is actively engaged in the stressful situation (evidenced by an increased heart rate or the number of heart beats per minute), and can be formed consciously and/or subconsciously (Seery, 2013). Further, these evaluations are considered dynamic, and are thought to be influenced by several interrelated factors (e.g., danger, familiarity, knowledge, and ability; Blascovich, 2008). Despite their discrete labels, it is worth noting that challenge and threat states are considered anchors of a single bipolar continuum, meaning that relative (rather than absolute) differences are typically examined (i.e., greater vs. lesser challenge or threat; Seery, 2011).

According to the BPSM, evaluating a stressful situation as a challenge elevates sympathetic-adrenomedullary activity, increasing blood flow to the brain and muscles by releasing catecholamines (epinephrine and norepinephrine) that raise cardiac activity and dilate the blood vessels (Seery, 2011). In contrast, evaluating a situation as a threat heightens pituitary-adrenocortical activity, minimizing blood flow by releasing cortisol that dampens sympathetic-adrenomedullary activity, causing little change or reductions in cardiac activity, and little change or constriction of the blood vessels (Seery, 2011). Accordingly, relative to a threat state, a challenge state is marked by greater cardiac output (amount of blood ejected from the heart in liters per minute) and lower total peripheral resistance (net constriction versus dilation in the arterial system), and these cardiovascular responses have been well established in the literature (Blascovich, 2008). Theoretically, the physiological response accompanying a challenge state is considered more efficient for energy mobilization and action, with greater blood flow increasing blood glucose levels and free fatty acids that fuel the nervous system and muscles, respectively (Dienstbier, 1989).

While the physiological response accompanying a challenge state is thought to provide an efficient spike of energy to the brain and muscles that prepares the body for immediate action, the pattern associated with a threat state is assumed to result in a more prolonged release of energy that inhibits physical actions (Cleveland et al., 2012). As a result, compared to a threat state, a challenge state is proposed to be better for the performance of tasks requiring anaerobic power (e.g., sprinting; Jones et al., 2009). However, to date, no research has investigated this prediction. Indeed, most of the research demonstrating the beneficial effects of a challenge state over a threat state has been limited to relatively fine motor tasks such as golf putting (e.g., Blascovich et al., 2004; Moore et al., 2012; 2013; Turner et al., 2013). For example, Turner et al. (2012) found that a cardiovascular pattern more consistent with a challenge state predicted greater accuracy in a competitive netball shooting task. Thus, to extend previous research, the present study offered an initial test of the relationship between challenge and threat states and performance during a competitive gross motor task requiring anaerobic power (i.e., sprint cycling).

Although growing research has highlighted the divergent effects of challenge and threat states on performance (Hase et al., in press), relatively little work has examined how these states might be related to other important outcomes (e.g., affective, perceptual, and cognitive responses). Indeed, Seery (2013) noted that while limited research has hinted that a challenge state is linked with more positive and less negative affect than a threat state (e.g., Schneider et al., 2012), more research is needed to clarify the association between these states and core affective experiences or basic feelings of pleasure and displeasure (Russell, 2003). Thus, the present study aimed to shed light on this relationship, which may be important given that core affect predicts a number of key variables in sport and exercise settings (e.g., enjoyment, adherence; Ekkekakis et al., 2013). Furthermore, given that psychological factors have been shown to impact perceptions of exertion or subjective ratings of strain, discomfort, or fatigue during physical tasks (e.g., self-efficacy; de Morree & Marcora, 2014), this study also extended previous research by providing the first test of the relationship between challenge and threat states and perceived exertion during a competitive sporting task. This is vital as perceived exertion is a critical concept in sport, and is associated with several key performance-related outcomes (e.g., exercise capacity, critical power; Eston, 2012).

While research has started to highlight that challenge and threat states might have different effects on attention (e.g., Moore et al., 2012; 2013), more research is warranted given the importance of attention for sports performance (Orlick & Partington, 1988). Indeed, in the theory of challenge and threat states in athletes (TCTSA), which applies the core predictions of the BPSM to sport, Jones et al. (2009) speculated that a threat state might lead to greater reinvestment than a challenge state - causing athletes to focus attention inward during the execution of a sporting task in an attempt to consciously control their movements (Masters & Maxwell, 2008). Interestingly, this notion was also postulated in the seminal study by Blascovich et al. (2004), who argued that a threat state might increase self-focus. However, only one study has examined this prediction using a relatively fine motor task, showing that golfers who were manipulated into a threat state before a pressurized golf putting task reported greater conscious processing than those who were encouraged into a challenge state (Moore et al., 2013). Thus, this study aimed to extend previous research and examine the link between challenge and threat states and self-focused attention during a competitive gross motor task. Indeed, directing attention towards movements has been shown to disrupt the performance of such tasks (e.g., Schucker et al., 2016).

Drawing on the aforementioned research, this study investigated the relationship between challenge and threat states and anaerobic power, core affect, perceived exertion, and self-focused attention during a competitive sprint cycling task. It was hypothesized that demand and resource evaluations (i.e., coping resources match or exceed task demands) and cardiovascular reactivity (i.e., relatively higher cardiac output and/or lower total peripheral resistance) more indicative of a challenge state would be associated with greater anaerobic power (i.e., larger increases in relative peak power output compared to baseline) during the pressurized sprint cycling task, relative to evaluations and reactivity more reflective of a threat state. Furthermore, it was predicted that demand and resource evaluations and cardiovascular reactivity more indicative of a challenge state would be related to more positive core affect, lower perceived exertion, and less self-focused or movement-related attention (e.g., cadence and power of legs) during the competitive sprint cycling task, compared to evaluations and reactivity more reflective of a threat state.

Method

Participants

Thirty-five healthy participants (22 male, 13 female; Mean ± *SD*: age = 26 ± 8 years; height = 1.66 ± 0.18 m; mass = 83 ± 24 kg) volunteered to take part in this study. All participants were recreationally active but did not regularly perform cycling-based exercise (i.e., less than once per month). Furthermore, all participants were non-smokers, and reported no known family history of cardiovascular and/or respiratory disease and no current injury and/or illness. Prior to testing, participants were informed of the study protocol and the possible risks of participation and, subsequently, provided written informed consent. All procedures were approved by an institutional ethics committee and conformed to the code of ethics of the Declaration of Helsinki.

Measures

Demand and resource evaluations. Two items from the cognitive appraisal ratio were used to assess demand and resource evaluations (Tomaka et al., 1993). Task demands were measured by asking, “How demanding do you expect the upcoming cycling task to be?” and personal coping resources were assessed by asking, “How able are you to cope with the demands of the upcoming cycling task?” Both items were rated on a 6-point Likert scale anchored between *not at all* (1) and *extremely* (6). Consistent with previous research (e.g., Moore et al., 2013), a demand resource evaluation score was calculated by subtracting evaluated demands from resources (range = −5 to +5), such that a negative value indicated an evaluation more reflective of a threat state (i.e., task demands exceed coping resources), and zero or a positive value indicated an evaluation more reflective of a challenge state (i.e., coping resources match or exceed task demands).

Cardiovascular reactivity. Heart rate, cardiac output, and total peripheral resistance were estimated using a non-invasive impedance cardiograph device (Physioflow Enduro, Manatec Biomedical, Paris, France). The validity of this device during rest and exercise has previously been established (see Charloux et al., 2000). The Physioflow measures impedance changes in response to a high-frequency (75 kHz) and low-amperage (1.8 mA) electrical current emitted via electrodes. Following preparation of the skin using disposable razors, abrasive electrode gel, and alcohol wipes (Sherwood et al., 1990), six spot electrodes (Physioflow PF-50, Manatec Biomedical, Paris, France) were positioned on the thorax of each participant: two on the supraclavicular fossa of the left lateral aspect of the neck, two near the xiphisternum at the mid-point of the thoracic region of the spine, one on the middle part of the sternum, and one on the rib closest to V6. After entering anthropometric details (i.e., height and mass), the Physioflow was calibrated over 30 heart cycles while each participant sat still and quietly in an upright position. Two resting systolic and diastolic blood pressure values were then taken (one before and another after the 30 heart cycles) using a digital blood pressure monitor (Omron M4 Digital BP meter, Cranlea & Co., Birmingham, UK). The mean blood pressure values were then entered into the Physioflow to complete the calibration procedure.

Heart rate, cardiac output, and total peripheral resistance were estimated continuously for five minutes during a resting period, and a further minute after the pressure manipulation instructions (see procedure for more details). To avoid the influence of movement artifacts, all participants remained seated, still, and quiet throughout both of these time periods, which were separated by approximately 60 seconds when the pressure manipulation instructions were delivered. Reactivity, or the difference between the final minute of rest and the minute after the pressure manipulation instructions, was examined for all three cardiovascular variables (as Moore et al., 2012). Heart rate reactivity is considered a cardiovascular marker of task engagement, with larger increases in heart rate reflecting greater engagement (a pre- requisite of challenge and threat states; Seery, 2011). Cardiac output and total peripheral resistance are acknowledged as cardiovascular indices that differentiate challenge and threat states, with a pattern consisting of higher cardiac output and lower total peripheral resistance reactivity more reflective of a challenge state (Seery, 2011). Heart rate and cardiac output were estimated directly by the Physioflow, while total peripheral resistance was calculated using the formula:

[mean arterial pressure x 80 / cardiac output] (Sherwood et al., 1990). Mean arterial pressure was calculated using the formula: [(2 x diastolic blood pressure) + systolic blood pressure / 3] (Cywinski, 1980). Unfortunately, due to technical problems with the Physioflow, cardiovascular data could not be recorded for two participants.

Anaerobic power. Participants visited the laboratory on a single occasion and performed a familiarization to the Wingate anaerobic test, followed by two experimental Wingate tests (i.e., baseline and pressurized Wingate tests). These tests were performed on the same electronically braked cycle ergometer (Lode Excalibur Sport V2, Groningen, The Netherlands), and in the same laboratory under consistent environmental conditions (Temperature = ~20°C; Humidity = ~20%). The fixed resistance for each test was set using a torque factor of 0.70 Nm/kg, such that the load applied to the flywheel was equivalent to 7% of each participant's body mass. Participants were provided with a five second countdown before the start of each test. To ensure an all-out effort, participants were instructed and strongly encouraged to attain their peak power as quickly as possible, to remain seated throughout, and to maintain their cadence as high as possible until instructed to stop. No time-based feedback was provided in order to prevent pacing. Power output was recorded second-by-second and then averaged into five-second time bins by recording software (Lode Ergometry Manager, Groningen, The Netherlands). Relative peak power was assessed during the baseline and pressurized Wingate tests, and was calculated by dividing the highest five- second power output by body mass (Driss & Vandewalle, 2013). To control for individual differences, a change score was created by subtracting relative peak power in the baseline Wingate test from relative peak power in the pressurized Wingate test. Thus, a positive score indicated an increase in power, a negative score reflected a decrease in power, and a score of zero indicated no change in power from the baseline to the pressurized Wingate test.

Core affect. The feeling scale was used to assess affective valence (Hardy & Rejeski, 1989). Specifically, participants rated how they felt during the pressurized Wingate test in terms of core affective sensations ranging from displeasure to pleasure. This single-item was rated on an 11-point bipolar scale ranging from *very bad* (-5) to *very good* (+5), with anchors at *Neutral* (0), and all odd integers including *bad* (-3), *fairly bad* (-1), *fairly good* (+1), and *good* (+3). The feeling scale has frequently been used to measure affective valence (Ekkekakis, 2013), and has been shown to correlate with other measures of core affect (e.g., affect grid [Russell et al., 1989]; Hall et al., 2002), and various key sport- and exercise-related constructs (e.g., current physical activity levels; Hardy & Rejeski, 1989).

Perceived exertion. The Borg 6-20 scale was used to assess perceived exertion (Borg, 1998). Specifically, participants rated the level of physical exertion they experienced during the pressurized Wingate test. This single-item was rated on a 15-point bipolar scale ranging from *no exertion at all* (6) to *maximal exertion* (20), with anchors at all odd integers including *extremely light* (7), *very light* (9), *light* (11), *somewhat hard* (13), *hard* (15), *very hard* (17), and *extremely hard* (19). This rating scale has commonly been employed to measure perceived exertion and/or exercise intensity (Borg, 1998), and has been associated with key sport-related variables (e.g., heart rate, oxygen uptake; Chen et al., 2002).

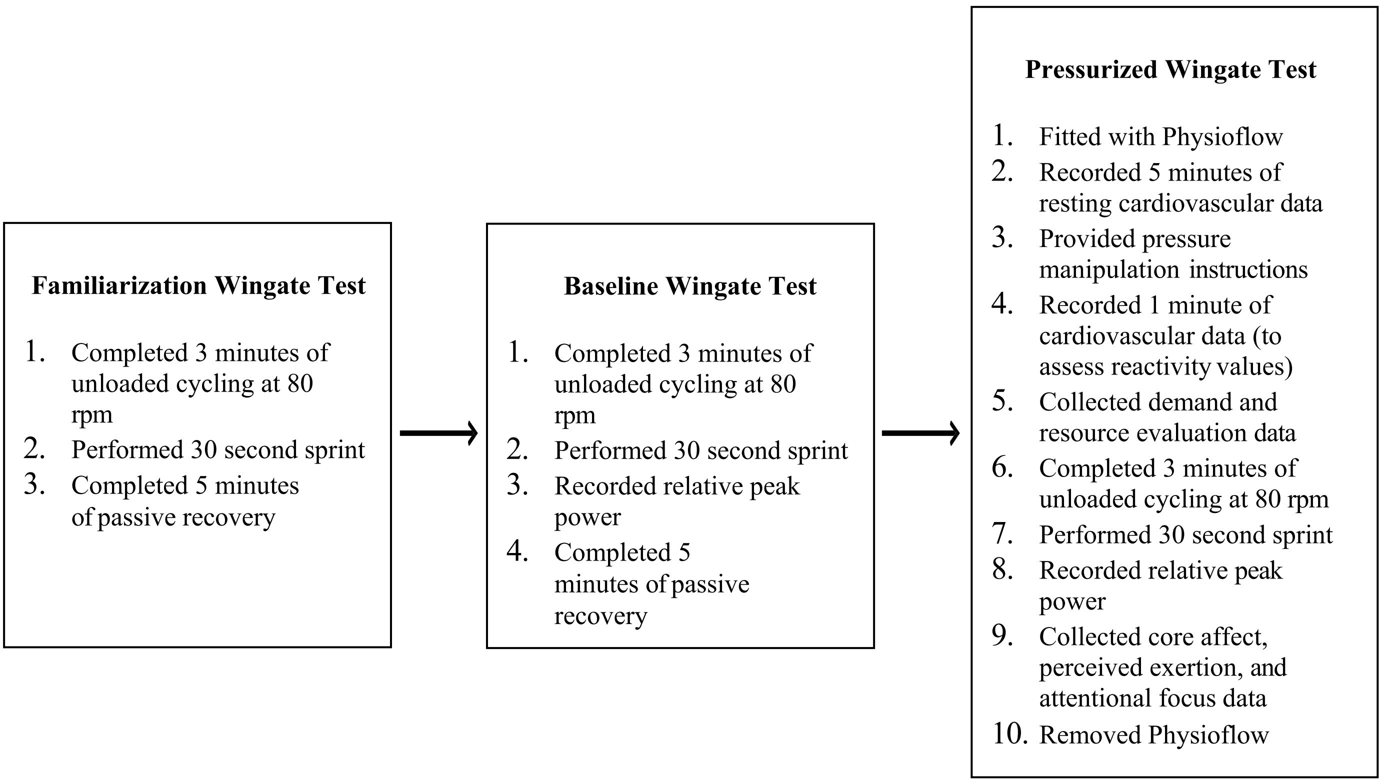
Self-focused attention. Congruent with previous research (e.g., Nibbeling et al., 2012), participants were asked where they predominately focused their attention during the pressurized Wingate test (i.e., one location, cue, or thought). Verbal statements regarding attentional focus were grouped into one of two categories: (1) movement-related (i.e., self-focused) – defined as cues or thoughts relating to skill execution including cadence of legs, power through legs, pressure on pedals, and fatigue sensations in the legs (e.g., "I focused on pedaling as fast as I could"), or (2) non-movement related – defined as cues or thoughts unrelated to movement including performance on previous tests, breathing rate, positive and negative self-statements, and outcomes associated with performance (e.g., "I focused on the camera, leaderboard, and prizes"). The attentional focus statements were analyzed and categorized by two independent raters, and inter-rater reliability was assessed using the interobserver agreement method (Thomas & Nelson, 2001). This method estimates reliability using a formula that divides the number of commonly coded attentional focus statements, by the sum of the commonly coded statements and statements coded differently. This analysis revealed a satisfactory level of agreement at 91%. While 18 participants (51%) reported focusing on movement-related cues or thoughts, 17 participants (49%) indicated that they focused on non-movement-related cues or thoughts.

Procedure

The study protocol is illustrated in Figure 1. Participants were tested individually and were instructed to arrive at the laboratory well hydrated, having avoided strenuous physical activity and alcohol for at least twenty-four hours, and caffeine ingestion for at least one hour. Initially, height and mass were recorded, and participants adjusted the seat and handle bar position of the cycle ergometer for comfort, and these positions remained constant throughout testing. Subsequently, participants performed three minutes of unloaded cycling at 80 rpm immediately followed by the familiarization Wingate test (i.e., 30 second sprint). Next, participants completed five minutes of passive recovery. Participants then performed three minutes of unloaded cycling at 80 rpm before completing the baseline Wingate test (i.e., 30 second sprint). After resting passively for another five minutes, participants were fitted with the Physioflow, which was then calibrated. Subsequently, participants sat still and quietly for five minutes while resting cardiovascular data were recorded.

All participants then received the same standardized instructions about a final competitive and pressurized Wingate test. These instructions were adapted from previous research (e.g., Moore et al., 2017), and emphasized: (1) the importance of the task, (2) that their performance (relative to the baseline Wingate test) would be compared against others via a published leader board, (3) that the task would be recorded on a digital video camera, (4) that participants who performed poorly (relative to their baseline Wingate test) would be interviewed at length, and (5) that participants who performed well (compared to their baseline Wingate test) would receive a prize. After these instructions, a further minute of cardiovascular data was recorded while participants sat still and quietly reflected on these instructions and the upcoming task. Participants then reported their demand and resource evaluations. Next, participants completed three minutes of unloaded cycling at 80 rpm followed by the pressurized Wingate test (i.e., 30 second sprint). Accordingly, the pressurized Wingate test was initiated approximately 20 minutes after the baseline Wingate test. Following the pressurized Wingate test, participants completed self-report measures of core affect and perceived exertion, and then verbally reported their focus of attention. Finally, the Physioflow was removed, and participants were thanked.

Figure 1. *A schematic representing the study protocol consisting of familiarization, baseline, and pressurized Wingate tests.*



Statistical analysis

A single challenge/threat index was calculated by converting each participant's cardiac output and total peripheral resistance reactivity values into z-scores and summing them (as Moore et al., 2017). Cardiac output was assigned a weight of +1 and total peripheral resistance a weight of -1 (i.e., reversed scored), such that a larger index corresponded with a cardiovascular pattern more reflective of a challenge state (i.e., relatively higher cardiac output and/or lower total peripheral resistance reactivity; Seery, 2011). Congruent with previous research (e.g., Turner et al., 2012), data with z-scores greater than two were removed (i.e., two values for each of demand resource evaluation score, challenge/threat index, change in relative peak power, and perceived exertion). Following these outlier analyses, all data were normally distributed (i.e., skewness and kurtosis z-scores did not exceed 1.96).

To examine task engagement, a dependent *t*-test was conducted on the heart rate reactivity data to establish that, in the sample as a whole, heart rate increased significantly from rest in response to the pressure manipulation instructions (i.e., heart rate reactivity greater than zero; as Seery et al., 2009). Next, descriptive statistics and bivariate correlations were calculated (see Table 1). A dependent *t*-test was then conducted to examine the differences in relative peak power between the baseline and pressurized Wingate tests, indicating whether anaerobic power was restored during the rest periods between the tests. Next, simple linear regression analyses were conducted to examine the extent to which challenge and threat states (i.e., demand resource evaluation score and challenge/threat index, analyzed separately) predicted anaerobic power (i.e., change in relative peak power from the baseline to the pressurized Wingate test), core affect, and perceived exertion. Beta values of 0.10, 0.30, and 0.50 represented small, medium, and large effect sizes, respectively (Cohen, 1992). Finally, logistic regression analyses were performed to investigate the degree to which challenge and threat states (i.e., demand resource evaluation score and challenge/threat index, analyzed separately) predicted self-focused attention (movement-related [coded 0] vs. non- movement related [coded 1]). All statistical analyses were performed using IBM SPSS Statistics 22 (SPSS Inc., Chicago, IL, USA), with significance set at $p < .05$ (Field, 2013).

Results

Table 1. *Means, standard deviations, and correlations for all variables*

	Mean	SD	1	2	3	4	5
1. Demand resource evaluation score	-0.61	1.22					
2. Challenge/threat index	0.08	2.24	-.11				
3. Change in relative peak power	0.39	1.51	.38*	-.04			
4. Core affect	-0.46	3.11	.53**	.27	.14		
5. Perceived exertion	18.30	1.61	-.33	-.16	-.17	-.29	
6. Self-focused attention	0.49	0.51	.34	.30	-.14	. 29	-.07

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

Task engagement

In the sample as a whole, heart rate increased significantly by an average of 2.09 ± 4.63 beats per minute from the final minute of rest to after the pressure manipulation instructions, before the pressurized Wingate test, $t(32) = 2.59$, $p = .014$, $d = 0.90$. The sample were therefore actively engaged in the test, enabling further examination of challenge and threat states (via demand resource evaluation score and challenge/threat index).

Anaerobic power

In the entire sample, there was no significant difference between the relative peak power achieved in the baseline (10.95 ± 2.68 W/kg) and pressurized (11.31 ± 2.86 W/Kg) Wingate tests, $t(32) = -1.16$, $p = .254$, $d =$

0.41, indicating anaerobic power was restored during the rest periods between the tests. Demand resource evaluation score accounted for a significant proportion of variance in change in relative peak power, $R^2 = .12$, $\beta = .38$, $p = .035$, *95% CI* = 0.04 to 0.90. Evaluating the pressurized Wingate test as more of a challenge (i.e., coping resources match or exceed task demands), as opposed to a threat (i.e., task demands exceed coping resources), was associated with a greater increase in relative peak power (compared to the baseline Wingate test). However, challenge/threat index did not account for a significant proportion of variance in change in relative peak power, $R^2 = .03$, $\beta = -.04$, $p = .843$, *95% CI* = -0.28 to 0.23.

Core affect

Demand resource evaluation score accounted for a significant proportion of variance in core affect, $R^2 = .26$, $\beta = .53$, $p = .002$, *95% CI* = 0.55 to 2.12. Evaluating the pressurized Wingate test as more of a challenge (i.e., coping resources match or exceed task demands) was related to a more positive affective response (i.e., greater pleasure) than evaluating the test as more of a threat (i.e., task demands exceed coping resources). However, challenge/threat index failed to account for a significant proportion of variance in core affect, $R^2 = .04$, $\beta = .27$, $p = .135$, *95% CI* = -0.12 to 0.83.

Perceived exertion

Demand resource evaluation score did not account for a significant proportion of variance in perceived exertion, $R^2 = .08$, $\beta = -.33$, $p = .066$, *95% CI* = -0.92 to 0.03. While nonsignificant, this result equated to a medium effect size and revealed a potentially meaningful descriptive trend (Cohen, 1992), suggesting that evaluating the pressurized Wingate test as more of a challenge (i.e., coping resources match or exceed task demands) was marginally associated with lower perceived exertion compared to evaluating the test as more of a threat (i.e., task demands exceed coping resources). However, challenge/threat index failed to account for a significant proportion of variance in perceived exertion, $R^2 = .01$, $\beta = -.16$, $p = .394$, *95% CI* = -0.38 to 0.16.

Self-focused attention

Demand resource evaluation score did not account for a significant proportion of variance in self-focused attention, $exp(\beta) = 1.90$, $\beta = .64$, $p = .070$, *95% CI* = 0.95 to 3.80. While nonsignificant, a potentially meaningful descriptive trend indicated that participants who evaluated the pressurized Wingate test as more of a challenge (i.e., coping resources match or exceed task demands) were more likely to focus on cues or thoughts unrelated to their movement (e.g., breathing, motivational self-statements) than participants who evaluated the test as more of a threat (i.e., task demands exceed coping resources). However, challenge/threat index failed to account for a significant proportion of variance in self-focused attention, $exp(\beta) = 1.34$, $\beta = .29$, $p = .102$, *95% CI* = 0.94 to 1.91.

Discussion

The physiological response accompanying a challenge state is thought to provide an increase in blood flow and energy supply to the brain and muscles that prepares the body for immediate action (Cleveland et al., 2012). Accordingly, relative to a threat state, a challenge state is thought to facilitate greater anaerobic power (e.g., sprinting; Jones et al., 2009). However, no research has investigated this notion, with existing work limited to relatively fine motor tasks (e.g., golf putting; Moore et al., 2012). Furthermore, despite growing research into the relationship between challenge and threat states and performance (Hase et al., in press), relatively few studies have examined whether these states are associated with other important affective, perceptual, and cognitive outcomes. Thus, this study investigated the relationship between challenge and threat states and anaerobic power, core affect, perceived exertion, and self-focused attention during a competitive sprint cycling task.

The heart rate reactivity data revealed that the sample were actively engaged with the pressurized Wingate test, as evidenced by an average increase of 2 bpm in anticipatory heart rate, allowing further examination of challenge and threat states (via demand resource evaluation score and challenge/threat index; Seery, 2011). As hypothesized, evaluating the pressurized Wingate test as more of a challenge was related to greater anaerobic power (i.e., increases in relative peak power from the baseline Wingate test) compared to evaluating the test as more of a threat. This finding supports the BPSM (Blascovich, 2008), and is consistent with previous research showing that challenge evaluations are linked with better performance than threat evaluations (Hase et al., in press). For example, Moore et al. (2013) found that golfers who evaluated an important competition as a challenge shot lower scores than golfers who evaluated the competition as a threat. To the authors' knowledge, this is the first study to demonstrate that challenge and threat might have divergent effects on gross motor performance. In addition, this study extends previous research which has tended to focus on physiological demands (Menaspa et al., 2015), and suggests that pre-competition psychological responses to stress may influence sprint cycling performance.

While the above finding is novel, challenge and threat states are proposed to have divergent effects on anaerobic power predominately because of the different physiological responses accompanying these states (Jones et al., 2009). However, contrary to our hypothesis and theoretical predictions (Blascovich, 2008; Jones et al., 2009), challenge/threat index was not related to anaerobic power. This finding is inconsistent with research which has typically shown that a cardiovascular response more reflective of a challenge state is associated with superior performance (Hase et al., in press). While this unexpected result may question the importance of the physiological response accompanying a challenge state for anaerobic power, it is important to acknowledge several methodological factors. First, repeated exposure to a task dampens cardiovascular responses (Kelsey et al., 1999). Thus, cardiovascular reactivity, which was assessed before the pressurized Wingate test, might have been attenuated by prior exposure to the task during the familiarization and baseline Wingate tests. Second, although the rest period was sufficient to permit restoration of anaerobic power, it is possible that the physiological system was still disrupted by the intense exercise during the baseline Wingate test, when cardiovascular reactivity was recorded before the pressurized Wingate test. These factors could have reduced measurement sensitivity and thus impaired our ability to accurately detect the psychological component of cardiovascular reactivity (i.e., underlying demand and resource evaluations; Blascovich & Mendes, 2000). Indeed, the weak association between demand resource evaluation score and challenge/threat index supports this notion. To minimize the influence of prior exercise on the assessment of cardiovascular reactivity, future research should separate tests by at least 48 hours (Harbili, 2015).

Following calls for more research into the relationship between challenge and threat states and core affective experiences (Seery, 2013), the results revealed that evaluating the pressurized Wingate test as more of a challenge was related to a more positive affective response (i.e., greater pleasure or less displeasure) compared to evaluating the test as more of a threat. This finding supports our hypothesis and is consistent with the results of existing research (Schneider, 2004). For example, Schneider et al. (2012) found that evaluating a mental arithmetic task as more of a threat was related to less positive and more negative affect than evaluating the task as a challenge. This is the first study to demonstrate that challenge and threat evaluations are linked with divergent affective responses during a competitive sporting task. This is an important finding given that in-task affective responses predict motivation for, and adherence to, exercise-related tasks in the future, with individuals more likely to engage with tasks they find more pleasurable (Rhodes & Kates, 2015). However, it should be noted that, in contrast to our hypothesis, challenge/threat index was not related to affect, possibly due to the reduced sensitivity in the measurement of cardiovascular reactivity caused by the methodological factors discussed above (e.g., prior exercise).

Although challenge/threat index was also not associated with perceived exertion, a nonsignificant but potentially meaningful descriptive trend revealed that evaluating the pressurized Wingate test as more of a challenge was marginally associated with lower perceived exertion, compared to evaluating the test as more of a threat. Thus, in line with our hypothesis, participants who viewed the competitive sprint cycling task as a challenge tended to report experiencing less strain, discomfort, or fatigue than those who viewed it as a threat. While this descriptive trend should be interpreted cautiously because it was not statistically significant, it did equate to a medium effect size (Cohen, 1992), highlighting that the relationship may be worth investigating in future research. Indeed, given that perceived exertion negatively correlates with a number of key performance-related variables (e.g., exercise capacity; Eston, 2012), this finding could potentially elucidate the mechanisms through which challenge and threat evaluations influence the performance of physically-demanding tasks. To our knowledge, this is the first study to show a possible relationship between challenge and threat evaluations and perceived exertion, and adds to previous work highlighting other salient psychological determinants (de

Morree & Marcora, 2014). For instance, McCauley and Courneya (1992) found that participants with higher self-efficacy reported lower exertion during cycling exercise than those with lower self-efficacy.

A nonsignificant, but potentially meaningful descriptive trend also showed that evaluating the pressurized Wingate test as more of a challenge was marginally related to less self-focused attention, with attention directed towards non-movement related cues or thoughts such as previous performance, breathing rate, motivational self-statements, or performance- contingent outcomes. In contrast, evaluating the test as more of a threat was marginally associated with greater self-focused attention, with attention directed towards movement- related cues or thoughts such as cadence, power and fatigue of legs, or pressure on the pedals. While this descriptive trend should be interpreted cautiously because it was not statistically significant, it does offer some support to the predictions of previous researchers and the TCTSA (Blascovich et al., 2004; Jones et al., 2009). Indeed, these authors proposed that a threat state might cause athletes to reinvest, or focus attention inward, in an attempt to consciously control their movements - an act which hinders task execution (Masters & Maxwell, 2008). This study adds to the paucity of research that has tested this proposition to date, with only one study by Moore et al. (2013) demonstrating that athletes manipulated into a threat state tend to reinvest or control movements more than athletes manipulated into a challenge state during a pressurized sporting task. However, it should be noted that, in contrast to our hypothesis, challenge/threat index was not related to self-focused attention, possibly owing to the reduced sensitivity in the measurement of cardiovascular reactivity caused by the methodological factors discussed above (e.g., prior exercise).

The findings of this study have some interesting implications. From a theoretical perspective, they suggest that the BPSM might be a useful framework to understand how pre- competition psychophysiological responses to stress influence physically-demanding tasks (e.g., sprint cycling). Moreover, from an applied perspective, they highlight that practitioners should encourage their athletes to view high-pressure competition as a challenge (i.e., coping resources match or exceed task demands) to facilitate better performance. Interventions such as imagery (e.g., Williams et al., 2010) and arousal reappraisal (e.g., Moore et al., 2015) might prove useful in this regard. Despite these implications, this study is not without its limitations. First, while untrained cyclists were recruited to control for the proposed influence of experience, skill, and ability on challenge and threat states (Blascovich, 2008), the novice sample limits generalizability, and so future research should replicate this study with elite athletes (Swann et al., 2015). Second, although the short task duration meant that retrospective measures were used to assess key variables (e.g., self-focused attention), such measures are open to bias caused by limitations in memory and/or attempts to salvage self- esteem (Shiffman et al., 1997). Thus, future research is encouraged to employ in-task measures that overcome this issue (e.g., think aloud; Whitehead et al., 2015). To improve the generalizability of the results, future research should also examine how challenge and threat states effect the performance of different power-based tasks (e.g., countermovement jump) and tasks that require muscular endurance (e.g., cycling time trial).

Conclusion

In conclusion, the present study investigated the relationship between challenge and threat states and anaerobic power, core affect, perceived exertion, and self-focused attention during a competitive sprint cycling task. Evaluating the test as more of a challenge (i.e., coping resources match or exceed task demands) was associated with greater increases in relative peak power and a more positive affective response, and marginally related to lower perceived exertion and less self-focused attention. However, challenge/threat index did not predict any variable. While the findings question whether the physiological pattern underlying a challenge state facilitates anaerobic power, they highlight the benefits of evaluating a physically-demanding gross motor task as a challenge.

References

Blascovich, J., 2008. Challenge and threat, in: Elliot A.J. (Ed.), Handbook of approach and avoidance motivation. Psychology Press, New York, pp. 431-445.

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., Seery, M.D., Mugridge, C.A., Norris, R.K., Weisbuch, M., 2004. Predicting athletic performance from cardiovascular indexes of challenge and threat. J Exp Soc Psychol. 40, 683-688.

Blascovich, J., Tomaka, J., 1996. The biopsychosocial model of arousal regulation. Adv Exp Soc Psychol. 28, 1-52.

Borg, G., 1998. Borg's perceived exertion and pain scales, Human Kinetics, Champaign. Cavendish, M., 2014. At speed: My life in the fast lane, Ebury Press, London.

Charloux, A., Lonsdorfer-Wolf, E., Richard, R., Lampert, E., Oswald-Mammosser, M., Mettauer, B., et al. 2000. A new impedance cardiograph device for the non-invasive evaluation of cardiac output at rest and during exercise: Comparison with the "direct" Fick method. Eur J Appl Physiol. 82, 313-320.

Chen, M.J., Fan, X., Moe, S.T., 2002. Criterion-related validity of the Borg ratings of perceived exertion scale in healthy individuals: A meta-analysis. J Sport Sci. 20, 873- 899.

Cleveland, C., Finez, L., Blascovich, J., Ginther, N., 2012. For better or for worse: The effect of superior or inferior teammate performance on changes in challenge/threat cardiovascular responses. Eur J Work Organ Psy. 21, 681-717.

Cohen, J., 1992. A power primer. Psychol Bull. 112, 155-159.

Cywinski, J., 1980. The essentials in pressure monitoring, Martinus Nijhoff Publishers, Boston.

De Morree, H.M., Marcora, S.M., 2014. Psychobiology of perceived effort during physical tasks, in: Gendolla, G.H.E., Tops, M., Koole, S.L. (Eds.), Handbook of biobehavioral approaches to self-regulation. Springer, New York, pp. 255-270.

Dienstbier, R.A., 1989. Arousal and physiological toughness: Implications for mental and physical health. Psychol Rev. 96, 84-100.

Driss, T., Vandewalle, H., 2013. The measurement of maximal (anaerobic) power output on a cycle ergometer: A critical review. Biomed Res Int.

Ekkekakis, P., 2013. Affect, mood, and emotion, in: Tenenbaum G., Eklund R.C., Kamata, A. (Eds.), Measurement in sport and exercise psychology. Human Kinetics, Champaign, 321-519.

Ekkekakis, P., Hargreaves, E.A., Parfitt, G., 2013. Invited guest editorial: Envisioning the next fifty years of research on the exercise-affect relationship. Psychol Sport Exerc. 14, 751-758.

Eston, R., 2012. Use of ratings of perceived exertion in sports. Int J Sport Physiol. 7, 175-182. Field, A., 2013. Discovering statistics using SPSS, Sage, Washington.

Hall, E.E., Ekkekakis, P., Petruzzello, S.J., 2002. The affective beneficence of vigorous exercise revisited. Brit J Health Psych. 7, 47-66.

Hardy, C.J., Rejeski, J.W., 1989. Not what, but how one feels: The measurement of affect during exercise. J Sport Exercise Psy. 11, 304-317.

Harbili, S., 2015. The effect of different recovery duration on repeated anaerobic performance in elite cyclists. J Hum Kinet. 49, 171-178.

Hase, A., O'Brien, J., Moore, L.J., Freeman, P., in press. The relationship between challenge and threat states and performance: A systematic review. Sport Exerc Perform.

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

Kelsey, R.M., Blascovich, J., Tomaka, J., Leitten, C.L., Schneider, T.R., Wiens, S., 1999. Cardiovascular reactivity and adaptation to recurrent psychological stress: Effects of prior task exposure. Psychophysiology. 36, 818-831.

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

Masters, R.S.W., Maxwell, J.P., 2008. The theory of reinvestment. Int Rev Sport Exerc Psy. 1, 160-183.

McCauley, E., Courneya, K.S., 1992. Self-efficacy relationships with affective and exertion responses to exercise. J Appl Soc Psychol. 22, 312-326.

Menaspà, P., Quod, M., Martin, D. T., Peiffer, J. J., Abbiss, C. R., 2015. Physical demands of sprinting in professional road cycling. Int J Sport Med. 36, 1058-1062.

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.

Moore, L.J., Vine, S.J., Wilson, M.R., Freeman, P., 2015. Reappraising threat: How to optimize performance under pressure. J Sport Exercise Psy. 37, 339-343.

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. J Sport Exercise Psy. 35, 551-562.

Moore, L.J., Young, T., Freeman, P., Sarkar, M., 2017. Adverse life events, cardiovascular responses, and sports performance under pressure. Scand J Med Sci Spor. 28, 340- 347.

Nibbeling, N., Oudejans, R.R.D., Dannen, H.A.M., 2012. Effects of anxiety, a cognitive secondary task, and expertise on gaze behavior and performance in a far aiming task. Psychol Sport Exerc. 13, 427-435.

Orlick, T., Partington, J., 1988. Mental links to excellence. Sport Psychol. 2, 105-130.

Rhodes, R.E., Kates, A., 2015. Can the affective response to exercise predict future motives and physical activity behavior? A systematic review of published evidence. Ann Behav Med. 49, 715-731.

Russell, J.A., 2003. Core affect and the psychological construction of emotion. Psychol Rev. 110, 145-172.

Russell, J.A., Weiss, A., Mendelsohn, G.A., 1989. Affect grid: A single item scale of pleasure and arousal. J Pers Soc Psychol. 57, 494-502.

Schneider, T.R., 2004. The role of neuroticism on psychological and physiological stress responses. J Exp Soc Psychol. 40, 795-804.
Schucker, L., Fleddermann, M., de Lussanet, M., Elischer J., Bohmer, C., Zentgraf, K., 2016. Focusing attention on circular pedaling reduces movement economy in cycling. Psychol Sport Exerc. 27, 9-17.
Schneider, T. R., Rench, T. A., Lyons, J. B., Riffle, R. R., 2012. The influence of neuroticism, extraversion, and openness on stress responses. Stress Health, 28, 102-110.
Seery, M.D., 2011. Challenge or threat? Cardiovascular indexes of resilience and vulnerability to potential stress in humans. Neurosci Biobehav R. 35, 1603-1610.
Seery, M.D., 2013. The biopsychosocial model of challenge and threat: Using the heart to measure the mind. Soc Pers Psychol Compass. 7, 637-653.
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.
Sherwood, A., Allen, M., Fahrenberg, J., Kelsey, R., Lovallo, W., van Doornen, L., 1990. Methodological guidelines for impedance cardiography. Psychophysiology. 27, 1-23.
Shiffman, S., Hufford, M., Hickcox, M., Paty, J.A., Gnys, M., Kassel, J.D., 1997. Remember that? A comparison of real-time versus retrospective recall of smoking lapses. J Consult Clin Psych. 65, 292-300.
Swann, C., Moran, A., Piggott, D., 2015. Defining elite athletes: Issues in the study of expert performance in sport psychology. Psychol Sport Exerc. 16, 3-14.
Thomas, J.R., Nelson, J.K., 2001. Research methods in physical activity, Human Kinetics, Champaign.
Tomaka, J., Blascovich, J., Kelsey, R.M., Leitten, C.L., 1993. Subjective, physiological, and behavioral effects of threat and challenge appraisal. J Pers Soc Psychol. 65, 248-260.
Turner, M.J., Jones, M.V., Sheffield, D., Cross, S.L., 2012. Cardiovascular indices of challenge and threat states predict competitive performance. Int J Psychophysiol. 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 challenge and threat states. J Sport Exercise Psy. 35, 387-397.
Whitehead, A.E., Taylor, J.A., Polman, R.C., 2015. Examination of the suitability of collecting in event cognitive processes using think aloud protocol in golf. Front Psychol. 6 (1083), 1-12.
Williams, S.E., Cumming, J., Balanos, G.M., 2010. The use of imagery to manipulate challenge and threat appraisals in athletes. J Sport Exercise Psy. 32, 339-358.