REVISE MS: PSE_2020_7

Stress Appraisals Influence Athletic Performance and Psychophysiological Response during 16.1km Cycling Time Trials

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Abstract

Objectives: We examined how stress appraisals were associated with emotions, coping behaviours, as well as subjective and objective measures of performance.

Design: Prospective field- and laboratory-based studies.

Methods: In Study 1, 192 athletes completed process-oriented psychometrics pertaining to the aforementioned constructs throughout a sporting competition. Study 2 utilised an experimental design to assess the causal influence of stress appraisals on performance, cortisol, and psychological variables. Thirty gender-matched athletes were randomly assigned to either a stress appraisal (e.g., challenge, threat, benefit, or harm/loss) or the control group. Participants completed three 16.1km cycling time trials (TT) on a cycle ergometer, with their appropriate stress appraisal engendered via falsified performance feedback throughout the final TT. Salivary cortisol samples and psychometrics (e.g., appraisals, emotions, and coping) were collected before and after each TT.

Results: The results of Study 1 revealed a sequential link between challenge stress appraisals and perceived goal attainment via pleasant emotions and task-oriented coping behaviours. Threat stress appraisals inversely related to goal attainment via unpleasant emotions and both distraction- and disengagement-oriented coping. In Study 2, no significant psychophysiological or performance differences were found across genders. The temporal orientation of stress appraisals influenced objective cycling TT performance. Benefit and harm/loss stress appraisals significantly facilitated or inhibited performance, respectively. Cortisol spikes were observed in the stress appraisal group's threat, challenge, and benefit, with a decline detected within the harm/loss group. Whilst the process of winning is physiologically stressful, the fear of defeat may be more stressful than losing itself.

Conclusion: Stress appraisals influence subjective and objective performance, as well as neuroendocrine and psychological responses to stress.

Stress Appraisals Influence Athletic Performance and Psychophysiological Response during 16.1km Cycling Time Trials

Athletes experience a variety of cognitive, emotional, and motivational states during sporting competitions, which are often interlinked with performance concerns (Lazarus, 2000; Moore & Bonagura, 2017). Throughout the previous two decades, a myriad of research has been rooted within the Cognitive-Motivational-Relational Theory of Emotions (Lazarus, 1999) to examine relationships between stress appraisals, emotions, coping behaviours, and performance within sport (Nicholls, Perry, & Calmeiro, 2014; Nicholls, Polman, & Levy, 2012). Despite this, comparatively few studies utilised methodologies that adequately reflect the reciprocally deterministic and causal nature of the aforementioned constructs. Until these theoretical niches are explored, scholars may not fully understand the causal nature of constructs within the stress process, and theory-guided interventions designed to improve performance and well-being could be limited. The mission of this research was to: (a) measure the stress process in a way more conceptually aligned to CMR theory and (b) establish causality through the measurement of stress appraisals, emotions, and coping behaviours across time points, in order to reflect an evolving stress process. For this purpose, we conducted two studies. Study 1 was prospective and Study 2 was experimental. In Study 1, we assessed stress appraisals, emotions, coping, and perceived goal attainment across three time-points. We extended these findings in Study 2 by manipulating the effects of the four types of stress appraisal during a 16.1 km cycling time trial, and then examined the resultant psychophysiological and performance responses. With these considerations in mind, the intricacies of CMR theory and its applicability to sporting contexts has been documented below.

Lazarus' Cognitive-Motivational-Relational Theory of Emotions

In the now seminal CMR theory, Lazarus (1999) proposed that the constructs of stress appraisals, emotions, and coping behaviours are intertwined both recursively and dynamically. In practice, this dictates that each construct can influence one another in a relationship characterised by its state of flux. One should not assume that these constructs are weighted equally, however: Lazarus posited that stress appraisals are the most important construct within his model. Stress appraisals are formulated via evaluations of an individual's person-environment relationship, and how this relationship has or may impact one's pursuit of his or her goals. When an individual *primary appraises* a stressful relationship, he or she evaluates how the current situation impacts upon his or her personal goals. This includes goal relevance (i.e., the importance of the goal), goal congruence (i.e., whether the upcoming event is facilitative or inhibitive to goal attainment), and ego involvement (i.e., how one's self-efficacy will be impacted). From this process, one of four primary appraisals are made if a person-environment relationship is deemed stressful. Firstly, a *harm/loss* stress appraisal is formed if a loss has occurred, such as suffering an injury. However, if a gain such as scoring a goal has occurred, then a *benefit* stress appraisal occurs. A *threat* stress appraisal is made if an upcoming scenario is deemed inhibitive to goal attainment, such as a forthcoming match against a superior player, whilst a *challenge* stress appraisal represents the prospect of making personal gains. Lazarus categorised challenge and benefit stress appraisals as gains, and threat and harm/loss stress appraisals as losses. In regards to CMR theory (Lazarus, 1999, 2000), challenge and threat stress appraisals have been extensively researched within field conditions (Nicholls et al., 2012, 2014), whilst laboratory-based research (Moore, Vine, Wilson, & Freeman, 2012; Moore, Wilson, Vine, Coussens, & Freeman, 2013) has tended to root itself within challenge and threat states, as conceptualised by the biopsychosocial model (Blascovich, 2008). The BPSM differs from CMR theory in its conceptualisation of appraisals as it considers challenge and threat states to be the 'end result' of the evaluation of demands and resources, rather than resulting from primary appraisal. Further, the BPSM does not take into account temporal orientation, with no psychophysiological profiles offered for past-oriented appraisal states benefit and harm/loss. Resulting from this field and laboratory research is the consensus that challenge appraisals facilitate improved athletic performance, whilst threat appraisals may inhibit athletic performance. However, these laboratory studies (Moore et al., 2012, 2013) have lacked control groups while field-based research lacks the enhanced causality of manipulation-based experimental research (Nicholls et al., 2014). Until these limitations are addressed, the extent to which stress appraisals causally influence performance in a range of sports shall remain unknown, as other variables may be at play. Lazarus (1999) also reported *secondary appraisal* in his model, which concerns one's evaluation of potential coping choices and the outcomes of particular strategies. Despite the misleading nature of the terms, primary and secondary appraisals do not occur sequentially, nor are they independent of one another (Lazarus, 1999).

It is from both primary and secondary appraisals of person-environment relationships that athlete emotional experiences are often generated (Lazarus, 1999). According to CMR theory, emotions are regarded as conscious, organised psychophysiological reactions to a stimulus that is either tangible or abstract (Lazarus, 2000). The classification of what constitutes an athletic emotional experience is often a contentious issue, with no agreed set list of emotions amongst researchers (Jones, Lane, Bray, Uphill, & Catlin, 2005). Whilst Lazarus (1999) posited the existence of 15 varying emotions (e.g. anger, anxiety, happiness, hope), sports scholars (Nicholls, Levy, Jones, Rengamani, & Polman, 2011) revealed that athletes report far fewer emotions during competition. Lazarus (2000) himself suggested that if CMR theory accurately replicated how emotions and coping impact athlete performance, then athletes should have an active understanding of what emotions they may experience when competing, and how best to cope with them. However, the nature and requirements of different sports means different emotions will be elicited within athletes, with varying facilitative or inhibitive impacts. It is for this reason, as well as aligning with previous research (Nicholls et al., 2012, 2014) that the broader categories of pleasant and unpleasant emotions were employed within this research.

The purposes of coping behaviours are to address and manipulate the person-environment relationship, as well as regulating and dictating past, present, and future emotional experiences. It is for this reason that Lazarus (2000) championed coping as the second most important construct of CMR theory. For the purposes of this research, coping can be understood as any cognitive or behavioural actions undertaken to control one's relationship with their environment. Although coping can be conceptualised in different ways, the three-dimensional approach developed by Gaudreau and

Blondin (2004) was used in this research. As such, coping was categorised into task-oriented coping (i.e., attempts to master a stressor), distraction-oriented (i.e., focusing on stimuli unrelated to the task), and disengagement-oriented coping (i.e., ceasing efforts to achieve one's goals). Although the relationship between coping and performance is well established (Nicholls, Taylor, Carroll, & Perry, 2016), the relationship between stress appraisals and performance could be more thoroughly investigated, particularly in relation to harm/loss and benefit stress appraisals (Nicholls et al., 2014) and within activities other than just fine motor tasks, such as golf putting. Exploring both past and future oriented appraisals may aid practitioners in the development of past- and future-oriented appraisal training to stimulate both pleasant emotions and athletic performance.

Stress Appraisals and Underlying Psychophysiological Mechanisms

Examining stress appraisals is not limited to psychometric assessments, however. With athlete emotional experiences intrinsically linked with neuroendocrine response (Parmigiani et al., 2009), cortisol – a steroid hormone managed via the hypothalamic-pituitary-adrenocortical (HPA) axis, has become a popular psychophysiological measure of psychophysiological stress. Neuroendocrine measurements can be taken during tasks and unlike self-report measures, they are not affected by social desirability (Seery, 2013). Contemporary psychophysiological research (Harvey, Nathens, Bandiera, & LeBlanc, 2010; Quested et al., 2011) has led to the development of neuroendocrine profiles relating to challenge and threat stress appraisals, with challenge and threat stress appraisals associated with suppressed and exaggerated cortisol expression respectively. What is more, extreme cortisol secretion has been linked to decreased performance (Elloumi et al., 2008), which may partially explain the inverse relationship between threat stress appraisals, unpleasant stress emotions (e.g., anxiety and dejection), and athletic performance. Surprisingly, little is known about neuroendocrine or psychophysiological correlates of past-oriented stress appraisals. Further research within this area could eventually develop psychophysiological profiles of Lazarus' (Lazarus, 1999, 2000) entire appraisal catalogue, which would guide athletes and their stakeholders in stress appraisal identification, as well as monitor the impact of efforts to reinforce or alter the said stress appraisal.

However, until further neuroendocrine research is undertaken, knowledge of stress appraisals and neuroendocrine response will be limited.

Study 1: Appraisals, Emotions, Coping, and Perceived Goal Attainment – a Path Analysis

Centred within Lazarus' (Lazarus, 1999, 2000) CMR theory, we measured stress appraisals, emotions, and coping behaviours, and subjective performance via goal attainment (Nicholls, Taylor, et al., 2016) across the course of real-life sporting competitions. We assessed these constructs in a way that reflects the constantly evolving nature of the stress process. Further, we built upon the work of Nicholls and colleagues (Nicholls et al., 2014) through the addition of both secondary appraisals and goal attainment, in order to understand how the controllability of a situation may influence challenge and threat appraisals. We predicted that goal relevance, goal congruence, coping potential, and future expectations would relate positively to challenge stress appraisals, and negatively to threat stress appraisals. As the construct of blame/credit relates to perceptions of control, we predicted that this would yield positive relationships with both challenge and threat stress appraisals. Following on from previous research (Nicholls et al., 2014) we predicted that positive paths would exist between challenge and pleasant emotions, as well as between threat and unpleasant emotions. Negative paths were also anticipated between challenge and unpleasant emotions, as well as between threat and pleasant emotions. Based upon research by scholars (Nicholls et al., 2012) we envisaged pleasant emotions producing a positive relationship with task-oriented coping, but negative relationships with distraction- and disengagement-oriented coping. In contrast, unpleasant emotions were expected to relate positively to distraction- and disengagement-oriented coping, but negatively to task-oriented coping. Finally, task-oriented coping was anticipated to reveal positive associations with all three goal constructs (e.g., mastery, self-referenced, and normative goals), with distraction- and disengagement-oriented coping expected to reveal negative associations due to recent findings in a meta-analysis that examine the coping and performance relationship (Nicholls, Taylor, et al., 2016).

Methods

Participants

Participants were 192 athletes (male *n* =144, female *n* = 47, unspecified *n* = 1) aged between 16 and 73 (*M* = 23.01, *SD* = 10.32) and with an average playing experience of 9.41 years (*SD* = 6.30). The athletes within our sample competed at international (*n* = 28), national (*n* = 23), county (*n* = 21), club (*n* = 112), and beginner (*n* = 8) levels. Athletes took part in both team (e.g., football, basketball) and individual sports (e.g., golf, triathlon).

Measures

The Pre-competitive Appraisal Measure (PAM; Wolf, Evans, Laborde, & Kleinert, 2015) is a seven-item questionnaire that measures primary and secondary appraisal on a 9-point Likert-type scale (1 = *strongly disagree* to 9 = *strongly agree*). As we wished to examine coping potential, we included the item 'I have the resources to cope with the upcoming competition', which was originally removed by Wolf et al due to poor model fit. The constructs of goal relevance and goal congruence care considered as primary appraisal constructs, with coping potential, blame/credit, and future expectations labelled as secondary appraisal constructs. Wolf and colleagues found that the PAM reported Cronbach's alpha coefficients ranging from .75 to .80, whilst Wolf, Eys, Sadler, and Kleinert (2015) reported adequate model fit in their research study.

The Stress Appraisal Measure (SAM; Peacock & Wong, 1990) assessed challenge and threat primary appraisals. The SAM contains four challenge and four threat items, with respondents answering questions such as 'I am keen to compete in my sport tomorrow', on a 5-point Likert-type scale (1 = *not at all* to 5 = *extremely*). In their three study paper to assess the validity of the SAM, Peacock and Wong reported acceptable Cronbach's alpha ratings for both threat (.65 & .75) and challenge (.66 & .74). Further, Perry, Nicholls, Clough, and Crust (2015) undertook both confirmatory factor analysis and exploratory structural equation modeling on the SAM, which displayed good factorial validity, including measurement invariance.

The Sports Emotion Questionnaire (SEQ; Jones et al., 2005) measured emotions. The SEQ is a 22-item questionnaire that measures two pleasant emotions (happiness and excitement) and three unpleasant emotions (anger, anxiety, and dejection) on a 5-point Likert-type scale (1 = *not at all* to 5 =

extremely). Jones and colleagues reported Cronbach's alpha ratings varying between .81 and .87. Support has been shown for the model fit and measurement invariance of the SEQ (Perry et al., 2015).

The Coping Inventory for Competitive Sports (CICS; Gaudreau & Blondin, 2002) assessed the use of coping strategies. In the CICS, 10 strategies are organised into three second-order dimensions consisting of task-, distraction-, and disengagement-oriented coping, rated on a 5-point Likert-type scale anchored by 1 = *not at all* and 5 = *very strongly*. Gaudreau and Blondin reported Cronbach's alpha ratings ranging from .67 to .87. Across a 10-week testing period, Fletcher (2008) found that the CICS was a strong measure which delivered meaningful data.

The Attainment of Sport Achievement Goals Scale (A-SAGS; Amiot, Gaudreau, & Blanchard, 2004) measured perceived goal attainment. The A-SAGS consists of 12 items, measuring three subscales: mastery, self-referenced, and normative goals. Mastery goals ascertain competence from perceived performance proficiency, self-referenced goals compare performance to previous efforts, and normative goals place emphasis on the extent of one's competitive success. These constructs were measured on a 7-point scale, anchored by 1 = *not at all* and 7 = *very strongly*. Amiot et al. reported that a global score of goal attainment calculated by regrouping all three subscales resulted in a Cronbach's alpha coefficients of .93. Support for the reliability and validity of the A-SAGS has also been found in previous research (Gaudreau & Antl, 2008).

Procedure

Following ethical approval from the university ethics committee, sports clubs were contacted via email and invited to pass details of the study on to their members. Informed consent was obtained from athletes aged 18 and over, whilst parental consent was gained for athletes aged 16 or 17. All participants completed paper copies of the questionnaire pack. The PAM (Wolf et al., 2015) and the SAM (Peacock & Wong, 1990) questionnaires were completed the evening before a competition. The SEQ was completed on the morning of the competition, and the CICS (Gaudreau & Blondin, 2002) and A-SAGS (Amiot et al., 2004) were completed within three hours of the competition ending, within the presence of a trained research assistant.

Data Analysis

Data were initially screened for missing data and outliers. Following this, a path analysis was conducted using sub-scale scores as observed variables. To account for departure from multivariate normality, we employed the robust maximum likelihood (MLR). We examined model fit using standardised parameter estimates, with the Comparative Fit Index (CFI) and Tucker-Lewis Index (TLI) presented as normed and non-normed incremental fit indices. The Standardized Root-Mean-Square Residual (SRMR) and Root Mean Square Error Approximation (RMSEA) were examined as absolute fit indices. To ascertain whether our model fit was satisfactory, we utilised Hu and Bentler's (1999) recommended fit indices barometers of CFI > .90, TLI > .90, SRMR < .08, RMSEA < .05 for acceptable model fit. Based on the outcome of the path analysis, the model was modified by removing non-significant paths to derive the most parsimonious model.

Results

Preliminary Analysis

On inspection, no missing data or outliers were found. No issues were found with univariate skewness (<2) or kurtosis (<2). As Cronbach's alpha assumes tau equivalence, McDonald's omega (ω) was chosen to measure internal consistency. For the PAM (Wolf, Evans, et al., 2015), omega coefficients of ω = .85 and ω = .73 for goal relevance and blame/credit were found respectively. However, as the constructs of goal congruence, coping potential, and future expectations were measured by one item, their omega was not calculated. Analysis of the SAM (Peacock & Wong, 1990) produced coefficients of ω = .66 for threat, and ω = .72 for challenge. In regards to the SEQ (Jones et al., 2005), coefficients of ω = .88 for unpleasant emotions, and ω = .88 for pleasant emotions were found. Further, the CICS (Gaudreau & Blondin, 2002) also revealed acceptable internal reliability, with coefficients of ω = .84, ω = .77, and ω = .79 found for the constructs of task-, distraction-, and disengagement-oriented coping respectively. Finally, examination of the A-SAGS (Amiot et al., 2004) revealed coefficients of $\omega = .82$, $\omega = .90$, and $\omega = .90$ for the constructs of mastery, self-referenced, and normative goals respectively.

Path Analysis

A path analysis was conducted using MPlus 7. We investigated the fit of the hypothesised sequential model presented (Figure 1) from primary and secondary appraisals, challenge and threat, emotions, coping strategies, and goal attainment. The resultant model fit of $\chi^2(62) = 139.45$, $p < .001$, CFI = .875, TLI = .809, SRMR = .094, RMSEA = .081 (90% confidence interval (CI) = .063, .099) was unsatisfactory. As such, we engaged in the iterative removal of all non-significant paths until all estimated paths were found to be significant, which led to the removal of goal congruence from the model as an exogenous variable. This resulted in a new model fit of $\chi^2(66) = 137.88$, $p < .001$, CFI = .883, TLI = .849, SRMR = .099, RMSEA = .075 (90% CI = .058, .093). With model fit still unsatisfactory, a further iterative process was undertaken in which paths were added based upon their modification index if there was a theoretically justifiable rationale. For example, variables could only be regressed on variables that occur before them in the model (Figure 1). This resulted in four paths being added, culminating in an excellent model fit of $\chi^2(62) = 79.28$, $p = .069$, CFI = .972, TLI = .961, SRMR = .070, RMSEA = .038 (90% CI = .000, .061).

Regarding stress appraisals, both goal relevance ($\beta = 0.43$, $p < .001$, 95% CI = 0.30, 0.55) and future expectations ($\beta = 0.33$, $p < .001$, 95% CI = 0.16, 0.50) were positively linked to challenge, whilst blame/credit ($\beta = 0.24$, $p = .001$, 95% CI = 0.11, 0.38) significantly predicted threat. A significant negative relationship was also observed between coping potential and threat ($\beta = -0.25$, $p = .003$, 95% CI = -0.41, -0.08).

Significant and positive paths were found between challenge and pleasant emotions ($\beta = 0.50$, $p < .001$, 95% CI = 0.39, 0.62), and between threat and unpleasant emotions ($\beta = 0.54$, $p < .001$, 95% CI = 0.42, 0.65). In relation to task-oriented coping, significant paths were found with pleasant emotions ($\beta = 0.18$, $p = .008$, 95% CI = 0.05, 0.31), goal relevance ($\beta = 0.27$, $p < .001$, 95% CI = 0.14, 0.40), and coping potential ($\beta = 0.25$, $p < .001$, 95% CI = 0.12, 0.37). Unpleasant emotions were found to significantly relate to both distraction- ($\beta = 0.39$, $p < .001$, 95% CI = 0.26, 0.52) and disengagement-oriented coping ($\beta = 0.36$, $p < .001$, 95% CI = 0.23, 0.49). As predicted, distraction- and disengagement-oriented coping significantly related to each other ($\beta = 0.32$, $p < .001$, 95% CI = 0.19, 0.45). Further, distraction-oriented coping was also found to significantly related to task-oriented coping ($\beta = 0.28$, $p < .001$, 95% CI = 0.16, 0.40).

Examination of goal attainment revealed a number of significant paths. Firstly, task-oriented coping significantly related to mastery ($\beta = 0.40$, $p < .001$, 95% CI = 0.28, 0.52), self-referenced ($\beta = 0.18$, $p = .01$, 95% CI = 0.04, 0.31) and normative goals ($\beta = 0.29$, $p < .001$, 95% CI = 0.17, 0.41). Meanwhile, distraction- and disengagement-oriented coping were negatively related to mastery goals (distraction- : $\beta = -0.13$, $p = .015$, 95% CI = -0.23, -0.03; disengagement-oriented coping: $\beta = -0.23$, $p < .001$, 95% CI = -0.32, -0.14). Self-referenced goals were negatively associated to disengagement-oriented coping ($\beta = -0.17$, $p = .004$, 95% CI = -0.28, -0.05). Finally, normative goals negatively related with threat ($\beta = -0.20$, $p < .001$, 95% CI = -0.29, -0.10). The resultant path analysis model can be found in Figure 2.

Discussion

Significant paths were found from primary and secondary appraisal through to goal attainment. This provides further support for the application of the CMR theory of emotions in sport, as well as building upon previous research (Nicholls et al., 2014) by examining primary appraisals more conceptually aligned to Lazarus' (1999, 2000) framework, which views appraisals, emotions, and coping as a changing process, thus requiring measurement across the course of real-life sporting competitions. Goal attainment was also added to the model, which is important for a sporting context.

The significant paths from challenge stress appraisals through to mastery, self-referenced, and normative goals, along with the negative path from threat through to mastery and self-referenced goals indicate an association between appraisals and the attainment of one's goals. This concurs with findings from previous research (Moore et al., 2013), and signifies the importance of athletes endeavouring to generate challenge appraisals during stressful competitions.

The examination of individual constructs within the primary appraisals of athletes provide a useful insight into the formation stress appraisals which are both facilitative and inhibitive for goal attainment. Indeed, it appears the combination of low athlete coping potential, as measured by secondary appraisal, and high levels of blame combine to formulate a threat appraisal, which in turn are negatively associated with normative goals. Conversely, coping potential was found to be directly associated with task-oriented coping behaviours, themselves associated with all three goal types. It may therefore be inferred that an athletes perception of control and their efficacy in undertaking their performance behaviours are a key determinant in appraisal formation and subsequent goal attainment (Wolf, Evans, et al., 2015). Indeed, with perceived external support leading to greater situational control and athletic performance (Freeman & Rees, 2009), practitioners are advised to furnish their athletes with a number of task-oriented coping strategies, such as seeking support and logical analysis. Further, with goal relevance also directly related to task-oriented coping, it appears that intrinsic motivation may predict task engagement. This is consistent with the literature (Amiot et al., 2004), and with coaches found to directly facilitate athlete motivation and consequent performance (Gillet, Vallerand, Amoura, & Baldes, 2010), should be noted by athlete stakeholders accordingly.

Distraction-oriented coping was found to significantly relate to both task- and disengagement-oriented coping. In regards to the former relationship, the employment of distraction-oriented coping may aid the preservation of physical and mental resources required for peak performance (Alberts, Martijn, Nievelstein, Jansen, & De Vries, 2008), as evidenced within athletes (Gaudreau & Blondin, 2004). In relation to the latter, it appears that distraction-oriented coping strategies may supplement disengagement-oriented strategies in an attempt to limit the potentially negative impact of unpleasant emotions. Whilst distraction-oriented strategies did negatively relate to mastery goals (Amiot et al., 2004; Gaudreau & Blondin, 2002), non-significant goal attainment findings have also been found (Gaudreau, Nicholls, & Levy, 2010). The theoretical possibility that distraction-oriented coping behaviours act as task- or disengagement-oriented coping facilitators is an exciting potential avenue for future research.

Interestingly goal congruence was not found to be a significant variable within our parsimonious model. This was unexpected, but may reflect a fallibility of single item measurement. It is arguable that the item “Performing well in the upcoming competition is desireable to me” does not truly encapsulate the nature of goal congruence, and may need revising in future research. This is a partial driver in our decision to investigate broader dimensions of primary and secondary appraisal in Study 2.

A limitation of Study 1, and other research in this field (Nicholls et al., 2012, 2014; Moore et al., 2012) is that we did not examine benefit and harm/loss stress appraisals. Whilst a limited amount research has investigated harm/loss stress appraisals (Bartholomew, Arnold, Hampson, & Fletcher, 2017), benefit stress appraisals generated by athletes have only been the subject of one qualitative examination (Nicholls et al., 2011). To provide a more parsimonious understanding of the stress process and subsequent goal attainment, both benefit and harm/loss stress appraisals need to be further explored. Development of this understanding would grant athlete stakeholders a greater knowledge of how their athlete may respond emotionally and behaviourally to a recent stimulus, as well as potentially aiding them in efforts to orient their athlete towards more performance facilitative appraisals. What is more, researchers would also be able to assess the impact that the temporal orientation (e.g. past- or future-oriented) of a stimulus may have within the stress process.

A further limitation of this study relates to its field-based cross-sectional nature, which is ecologically valid yet lacks definitive causality. Experimental research in which an athlete’s person-environment is suitably controlled and manipulated would provide scholars with more confidence that any significant psychological or performance changes were resulting from an athlete’s stress appraisal, as opposed to type I error. Whilst some experimental research has been undertaken by Moore and colleagues (2012, 2013) relating to challenge and threat states, researchers have not yet investigated the effects of stress appraisals on endurance performance. Understanding the implications of appraisals on endurance performance is important, so that these athletes can be offered evidence-based techniques. In addition, a controlled environment would also provide scholars with the opportunity to develop psychophysiological profiles through use of physiological stress markers such as cortisol. This is particularly important in relation to past-oriented appraisals, with no neuroendocrine or psychophysiological profiles currently existing. Taken together, these limitations within the literature dictate that only half of Lazarus' (1999, 2000) CMR stress appraisal catalogue has been reliably examined in a controlled environment. It is for these reasons that we decided to undertake Study 2.

Study 2: A Psychophysiological Examination of Lazarus' CMR Theory of Emotions via a Lab-Based 16.1 km Cycling Time Trial Task.

With scholars yet to examine the psychophysiological consequences of the four types of appraisals among athletes, Lazarus' (1999, 2000) CMR theory of emotions is yet to be fully examined within a sporting context. This is important because theoretically-based empirical research could lead to the eventual development of accurate psychophysiological appraisal profiles which could be used to characterise athletes appropriately (Parmigiani et al., 2009). From this, athlete stakeholders could subsequently undertake theory-guided actions in order to facilitate both optimum performance and athlete wellbeing. Until then our understanding of the stress process in regard to neuroendocrine response and resultant performance impact is limited, and thus requires investigation. The purpose of Study 2 was to measure stress appraisals, emotions, coping strategies, and objective performance in a controlled, laboratory-based cycling task. With stress appraisal theoretically being deemed the most important construct in Lazarus' (1999, 2000) CMR theory of emotions, and empirically in Study 1, we aimed to manipulate this construct within Study 2, and assess its influence on cortisol levels and cycling performance. Furthermore, we extended our measurement of CMR theory of emotions in Study 2 by also examining past-oriented stress appraisals of benefit and harm/loss.

We predicted that gain stress appraisals of challenge and benefit would result in superior performance in comparison to the control group, whilst the loss stress appraisals of threat and harm/loss would result in poorer performance when compared to the control group. Further, based upon previous findings (Harvey et al., 2010; Quested et al., 2011), which suggest that challenge and threat appraisals suppress and spike cortisol response respectively, we also predicted that both challenge and benefit groups would show significantly less salivary cortisol secretion, whilst threat and harm/loss would show significantly increased physiological response in comparison to the control group. Finally, we predicted that the psychological response of the challenge and threat groups would replicate Study 1's path analysis. Further, benefit and harm/loss were expected to mirror the results of their respective gain and loss groupings, challenge and threat.

Method

Participants

Thirty athletes were recruited via email to participate in this study, of which 19 identified cycling as their primary sport. All but five athletes were members of cycling clubs with experience of time trial conditions, who participated in physical activity training on average 5.5 times a week. Fifteen were male (age 34.67 ± 10.4; height 178.69 cm ± 7.92 cm; weight 81.71 kg ± 10.36 kg) and 15 were female (age 30.53 ± 9.37; height 167.19 cm ± 6.87 cm; weight 61.79 kg ± 8.65 kg). Before testing began, participants completed a Physical Activity Readiness Questionnaire (American College of Sports Medicine, 2013) designed to ensure that only ostensibly able individuals would be allowed to participate. The study inclusion criteria required athletes to be aged between 16-55 years, who trained at least three times a week, did not smoke, had no history of cardiovascular illness, and free from the consumption of substances which may affect salivary cortisol secretion at the time of the study. The protocol for this study was approved by a university ethics committee.

Self-Report Measures

Self-report measures were completed on each testing day, excluding familiarisation. Aligned to Study 1, participants completed the PAM (Wolf et al., 2015), and SAM (Peacock & Wong, 1990) to assess future-oriented stress appraisals, and the SEQ (Jones et al., 2005) to measure emotions before the task. Participant coping strategies were also measured similarly to Study 1, with an altered version of the CICS (Gaudreau & Blondin, 2002) completed after the time trial (TT). Some items were modified to fit the cycling task, whilst all items relating to 'distancing from others' and 'seeking support' were not deemed relatable to the task, and thereby removed. This resulted in a 28-item CICS. Finally, past-oriented stress appraisals were measured post-TT via use of an amended 8-item version of the SAM (Peacock & Wong, 1990). Modifications were made to future-oriented challenge and threat items to make them past-oriented. For example, the item "I can become a stronger person by competing today" which measured challenge was changed to "I've shown that I am a capable athlete", and thus measured benefit, whilst the item "I feel threatened and worried about tomorrow's competition" which measured threat was changed to "I felt disappointed with my performance" to measure harm/loss.

Physiological Response and Performance

Athletic performance was assessed by calculating the percentage time change between TT2 and TT3 completion times (Halson et al., 2002), whilst physiological response was measured via salivary cortisol levels – a marker commonly used by researchers to explore psychophysiological response to stress over time (Hellhammer, Wüst, & Kudielka, 2009). The authors decided on sampling salivary cortisol levels for a number of reasons. Firstly, due to its non-invasive procedure and more accurate reflection of unbound cortisol (in relation to serum total cortisol), it is viewed as the gold standard measurement (Vining, McGinley, Maksvytis, & Ho, 1983). Further, a meta-analysis conducted by Denson, Spanovic, and Miller (2009) has emphasised that stress appraisals and emotions directly impact HPA activation. As cortisol secretion induced by high intensity exercise takes up to 59 minutes to statistically significantly increase (Jacks, Sowash, Anning, McGloughlin, & Andres, 2002), cortisol was deemed a suitable measure of psychological stress during exercise. On the basis of research findings which indicate that menstrual cycle stage and oral contraceptive do not impact cortisol levels (Liening, Stanton, Saini, & Schultheiss, 2010), and given that there were an equal number of males and females within each testing group, participants of both genders underwent the same cortisol sampling procedure. Three saliva samples were taken on each testing day, excluding familiarisation, via salivettes (Sarstedt, Rommelsdorf, Germany). These were taken at baseline (TP1), immediate post-exercise (TP2), and 15 minutes post-exercise (TP3). Salivary cortisol levels peak 15 minutes post-HPA activation via psychological stressor (Quested et al., 2011), so there was sufficient time for all manipulations to take effect. Cortisol analysis was conducted via enzyme-linked immunosorbent assay kits as per the manufacturer's instructions (Sigma Aldrich, St Louis, USA).

Procedure

In accordance with the recommendations of Schweizer and Furley (2016), an a priori power analysis was conducted via use of G*Power 3.1 (effect size = .35, alpha = .05, power = .8), which indicated a minimum of 30 participants, equating to six participants per stress appraisal group (i.e., challenge, threat, benefit, harm/loss, and control). Each stress appraisal group was randomly allocated both three males and three females who completed three 16.1km TT's as quickly as possible on an SRM cycle ergometer (Schoberer Rad Mebtechnik, Konigskamp, Germany). With 16.1km TTs commonplace in cycling competitions, this provided ecological validity for our task (Sparks et al., 2016). As task familiarity is an indispensable factor when considering performance variance (Sparks et al.), a familiarisation session (TT1) was provided to all athletes but was not included in the analysis. All testing sessions occurred at the same time of day to avoid diurnal variation, and were separated by at least 72 hours to facilitate recovery. Participants were instructed to attend all testing sessions in a hydrated state, having not consumed caffeine on the day of testing or food one hour before, nor engaged in strenuous activity 24 hours prior.

Once all anthropometrical data had been taken, participants provided their first saliva sample (TP1), and began a five-minute warm up. Once the participant felt ready to start, the TT began. The SRM ergometer software recorded values for heart rate, cadence, power, distance, speed, and time each minute. In order to aid the deception, participants were only provided with how far (KM) they had cycled. Other than the manipulations imparted during TT3 (see Manipulation section), there was no communication between the researcher and participant. Following the TT completion, the TP2 saliva sample was taken. After 15 minutes of rest had elapsed, the final saliva sample was also taken (TP3) and the session ended.

Manipulation

Participants received stress appraisal manipulations during TT3 via standardised performance feedback. This excluded the control group, who received no feedback. To ensure that stress appraisal manipulations had the greatest possible impact, a number of task engagement measures were implemented. Firstly, whilst the study's purpose was kept intentionally vague, in order to not arouse suspicion of deception, the importance of the TT was constantly emphasised. Secondly, participants were told that they were competing against other cyclists of their gender to win either a £75 prize for first place or a £25 prize for second place. Participants were informed that these prizes would be allocated depending on their mean time for TT2 and TT3, which would also be displayed on an online leader board. In reality, all participants were entered into a draw to win one of four gift cards worth £100 each, regardless of their cycling performance. This draw was also balanced to ensure an equal amount of winners across genders. Participants were also informed that their performances were to be recorded via video camera that was placed one metre to the front left of the cycle ergometer. Finally, participants were told that the two slowest male and female cyclists would be required to take part in a 30-minute interview to discuss their poor performance. Such measures were implemented to mimic the social evaluation stressors that high-level athletes constantly face in real life (Noblet & Gifford, 2002). With the mission of this research aimed at aiding athletes deal with such stressors, the authors felt it necessary to engender high levels of stress within the participants. All manipulation measures were only deemed suitable for inclusion after due deliberation between the authors to ensure that participant wellbeing was never endangered. Further, participant wellbeing was monitored at all times by the lead researcher, with the participant free to withdraw at any time.

Participants received three stress appraisal manipulations over the course of the TT3 testing session, which related to the participants supposed performance from TT2 and their ongoing performance in TT3. These occurred pre-TT, at the halfway point of the TT (8km), and post-TT. The stress appraisal scripts, which are available upon request from the first author, were based on manipulations from previous research (Moore et al., 2012) and were devised by all members of the research team who possess detailed knowledge of the works of Lazarus (1999, 2000). As challenge stress appraisals are gain and future-oriented in nature, challenge group participants who were allocated to the challenge group were advised that they topped the study leader board, in their gender, at the halfway stage. As such, an impressive, but achievable, performance could result in them potentially being the fastest cyclist overall. Conversely, threat stress appraisal participants were advised that, at the halfway stage of the study, they were in last place in their gender group and were at real risk of being interviewed. Participants placed into the benefit or harm/loss groups were told that they were the last person to participate in the study, thus enabling a past-orientation to their feedback. Benefit participants were told that improving or maintaining their previous performance would see them top the leader board, whilst harm/loss participants were instructed that it was almost inevitable they would finish in the bottom two. At the subsequent manipulation time points, occurring at 8km and immediate post-TT, these stress appraisals were reinforced. Once the final saliva sample was provided fifteen minutes after completing TT3, the study ended and the participant received a full and thorough debrief about the true nature of the study and were asked to keep the study confidential.

Results

Demographics

A one-way ANOVA was initially conducted to assess the distribution of the randomisation process. This produced no significant differences across the groups in regard to age (males p = .54; females p = .70; overall p = .67), height (males p = 1.00; females p = .70; overall p = .95), weight (males p = .92; females p = .93; overall p = .98), or physical activity levels (males p = .51; females p = 90; overall p = .96).

Manipulation Checks

Independent-samples *t*-tests examined if the stress appraisals of challenge, threat, benefit, or harm/loss were engendered in the targeted groups. In accordance with guidelines (Sullivan & Feinn, 2012), all *p* values were supplemented with Hedges *g* corrected effect sizes, which are more suitable for smaller sample analysis than Cohen's *d* (Hedges & Olkin, 1985). With no manipulation provided to the control group, no manipulation check via *t*-test was required. Compared with the threat group, challenge produced a significantly larger challenge stress appraisal index value, $t(10) = 4.77$, $p = .001$, $g = 2.54$, and significantly less threat index value, $t(10) = 2.55$, $p = .03$, $g = 1.36$. Benefit was compared against harm/loss, and exhibited significantly higher levels of benefit, $t(10) = 3.57$, $p = .005$, $g = 1.90$, as well as significantly lower levels of harm/loss, $t(10) = 6.40$, $p < .001$, $g = 3.42$.

Self-Report Measures

McDonald's omega (ω) was chosen to measure internal consistency. Analysis of the PAM (Wolf et al., 2015) produced coefficients of ω = .69 (TT2) and ω = .85 (TT3) for goal relevance, as well as ω = .86 (TT2) and ω = .85 (TT3) for blame/credit. As in Study 1, omega was not calculated for the constructs of goal congruence, coping potential, and future expectations, as they were measured by one item only. The SAM (Peacock & Wong, 1990) revealed omega outputs of ω = .63 (TT2) and ω = .75 (TT3) for threat, along with ω = .65 (TT2) and ω = .79 (TT3) for challenge. Examination of the SEQ (Jones et al., 2005) could not calculate omega for unpleasant emotions at TT2, as there was perfect item agreement, whereby there was no variance among items in the scale. At TT3, unpleasant emotions produced a coefficient of ω = .90. Further SEQ scales yielded ω = .89 (TT2) and ω = .93 (TT3) for pleasant emotions. The revised CICS (Gaudreau & Blondin, 2002) delivered coefficients of ω = .72 (TT2) and ω = .91 (TT3) for task-oriented coping, ω = .91 (TT2) and ω = .89 (TT3) for distraction-oriented coping, and ω = .68 (TT2) and ω = .85 (TT3) for disengagement-oriented coping. Finally, the revised SAM (Peacock & Wong) produced outputs of ω = .87 (TT2) and ω = .85 (TT3) for harm/loss, as well as ω = .73 (TT2) and ω = .87 (TT3) for benefit. Following the internal consistency analysis, a factorial analysis of variance (ANOVA) was conducted to examine the psychological responses of athletes across the two competitive TTs. To account for any potential type I error resulting from multiple comparisons, Benjamini-Hochberg q was derived from determining the False Discovery Rate. The null hypothesis was rejected if and only if $p < q$ and the 95% confidence interval did not contain zero.

Primary and Secondary Appraisals

Between-group tests revealed no significant difference between groups for primary appraisal. However, an effect of $F(4) = 3.49$, $p = .021$, was found for secondary appraisal. This subsequently passed the FDR ($q = .025$). Pairwise comparisons revealed a significantly positive primary appraisal increase for benefit appraisal athletes from TT2 to TT3 ($p =.042$, $g = 0.87$), as well as a significant decrease for threat appraisal athletes from TT2 to TT3 ($p = .025$, $g = 0.73$). However, with the reported p values higher than the FDR q value ($q = .02$ and .01 respectively), the null hypothesis was not rejected. Participants in the threat and control groups also scored significantly lower levels of secondary appraisal during TT3 than TT2, with outputs of $p = .006$, $g = 0.90$ and $p = .044$, $g = 0.83$ respectively. Whilst the significance of the threat relationship passed the FDR ($q = .01$), the control group failed ($q = .02$). Finally, the benefit stress appraisal group produced a significantly more positive secondary appraisal for TT3 than both harm/loss ($p = .048$, $g = 2.16$) and threat ($p = .001$, $g = 1.94$), with challenge also significantly higher than threat ($p = .005$, $g = 1.70$). Following post-hoc analysis, only the relationship between benefit and threat failed the FDR, with respective q values of .015, .005, and .001.

Challenge and Threat Appraisals

Pairwise comparisons of each appraisal grouping produced significantly lower levels of challenge for TT3 (in comparison to TT2) for the groups of threat ($p = .003$, $g = 0.90$), harm/loss ($p = .015$, $g = .0.67$), and control ($p = .042$, $g = 0.64$). Whilst the control group did not pass the FDR ($q = .03$), both the threat ($q = .01$) and harm/loss ($q = .02$) group interactions did. A significant effect was found between challenge and threat for TT3, with challenge group participants displaying higher levels of challenge appraisal ($p = .011$, $g = 2.54$). However, with a FDR q value of .005, the null hypothesis was not rejected. Lastly, very large effects in relation to challenge appraisals were found during TT3 between challenge and the groups of harm/loss and control (p = .071, g = 1.57; and p = .071, g = 1.79 respectively).

Pleasant and Unpleasant Emotions

Examination of group pairwise comparisons indicated that the threat group experienced significantly less pleasant emotions during TT3 than TT2 (p = .025, g = 0.99), whilst harm/loss experienced more unpleasant emotions during TT3 than TT2 (p = .025, g = 0.63).
Benjamini-Hochburg post-hoc correction for multiple comparisons revealed that both of these interactions failed the FDR, with q values of .01 and .01.

Coping Strategies

Distraction-oriented coping strategies were found to significantly differ across groups, with a main effect of F(4) = 2.83, p = .046. However, this p value was not found to be lower than q = .0167. In relation to task-oriented coping, pairwise comparisons revealed a host of significant changes, including after post-hoc analyses, with challenge (p < .001, g = 1.60, q = .02), benefit (p < .001, g = 3.46, q = .01), harm/loss (p < .001, g = 1.15, q = .04), and control (p < .001, g = 1.52, q = .03) all higher during TT3. Threat stress appraisal participants used significantly more disengagement-oriented coping strategies during TT3 than TT2, including after post-hoc testing (p = .003, g = 0.86, q = .01). Harm/loss participants displayed a large increase effect in the amount of disengagement-oriented coping utilised in TT3 compared to TT2, with an output of p = .057, g = 0.81. A significant effect was also found between challenge and threat in relation to task-oriented coping during TT3, with challenge utilising such strategies more (p = .045, g = 1.48). This effect was not found to pass the FDR, however (q = .005).

Benefit and Harm/Loss Appraisals

Significant between-group effects were found for both benefit ($F(4) = 4.86$, $p = .005$) and harm/loss ($F(4) = 4.23$, $p = .009$), including after Benjamini-Hochberg post-hoc analyses (benefit: $q = .025$; harm/loss $q = .05$). Pairwise comparisons revealed significantly lower levels of harm/loss stress appraisal during TT3 for the benefit group when compared to TT2 ($p = .003$, $g = 1.13$), whilst the threat group portrayed significantly higher levels of harm/loss in TT3 than in TT2 ($p = .037$, $g = 0.53$). Following post-hoc testing, the null hypothesis was rejected in relation to the benefit group interaction ($q = .01$), and not rejected in relation to the threat group interaction ($q = .02$). During TT3, threat and harm/loss participant groups also exhibited significantly stronger harm/loss stress appraisals than challenge (threat: $p = .001$, $g = 1.94$, $q = .001$; harm/loss: $p = .004$, $g = 3.61$, $q = .015$) and benefit (threat: $p = .001$, $g = 1.81$, $q = .005$; harm/loss: $p = .01$, $g = 3.42$, $q = .02$). The threat group also displayed higher levels of harm/loss than the control group for TT3 after post-hoc testing ($p = .01$, $g = 1.38$, $q = .025$).

Including after post-hoc analyses, participants in the challenge and benefit groups exhibited higher benefit scores during TT3 than in TT2 (challenge: $p = .006$, $g = 1.30$, $q = .03$; benefit: $p = .017$, $g = 1.48$, $q = .04$), whilst threat and harm/loss scored significantly lower in TT3 than in TT2 (threat: $p < .001$, $g = 2.45$, $q = .02$; harm/loss: $p < .001$, $g = 1.65$, $q = .01$). Pairwise comparisons revealed that the high TT3 benefit scores by the benefit participant group produced very large effects in relation to those of the threat ($p = .002$, $g = 3.03$) and harm/loss ($p = .070$, $g = 1.90$) groups. Regarding the interaction involving the benefit and threat group, this was found to be significant after Benjamini-Hochberg analysis, with a q value equating to .015. Other findings included significantly stronger benefit stress appraisals during TT3 by the challenge group in comparison to both threat ($p < .001$, $g = 4.04$) and harm/loss ($p < .001$, $g = 2.94$), as well as significantly lower levels for the threat group compared to the control group ($p = .002$, $g = 1.92$). These findings were sustained following post-hoc analysis, with respective q values of .005, .01, and .02.

Physiological Response

Due to diurnal variation across participants, the decision was taken by the authors to analyse each groups cortisol results separately. In keeping with the cortisol meta-analysis conducted by Denson, Spanovic, and Miller (2009), effect size was deemed the most suitable expression of neuroendocrine response. Table 1 provides a summary of athlete physiological response across each time point. Whilst the challenge group did not differ across the first two time points, cortisol levels increased at TT3 TP3 (in comparison to TT2 TP3), creating a moderate effect of $g = 0.52$. A similar pattern was displayed in the threat group, with TT3 TP3 stress levels heightening to produce a large effect of $g = 0.90$. The benefit group witnessed an initial cortisol spike of $g = 0.45$ between TT2 TP1 and TT3 TP1, which decreased to $g = 0.29$ from TT2 TP3 to TT3 TP3. Participants in the harm/loss group displayed lower levels of cortisol during TT3, with moderate to large effects found at TP1 ($g = 0.78$) and TP3 ($g = 0.74$). Finally, moderately higher levels were found across the first two time points of TT3 ($g = 0.50$ and $g = 0.57$, respectively), which eventually dropped at TP3 to trivial levels ($g = 0.09$).

Time Trial Performance

As appraisal manipulations may have had varying performance impacts across participants, the authors decided that dichotomous measures of performance change were insufficient, and that a performance trichotomy, which accounted for significant improvement, significant decline, or insignificant performance variation was required. As such, odds ratios calculated through Penalized Multinomial Logistic Regression (PMLR) were selected as a suitable expression of performance change. PMLR is undertaken through the penalization of the maximum likelihood estimation using the Jeffrey's Prior (Bull, Lewinger, & Lee, 2005), and has been championed by scholars (Bull, Lewinger, & Lee, 2007; Bull, Mak, & Greenwood, 2002; Devika, Jeyaseelan, & Sebastian, 2016) as suitable for smaller samples and for data sets in which perfect separation has occurred. With perfect separation discovered within the benefit group (i.e. all participants significantly improving) during the analytical process, the penalization of the maximum likelihood estimate meant no further action was required. In order to create the nominal values required for the regression, a performance change threshold of 1.1% coefficient of variation (CV; taken from Sparks et al., 2016) was utilised. Due to its similarity to CV, individual participant performance change was calculated. PMLR was conducted for each appraisal group (with the control group and insignificant performance variation acting as reference categories to draw resultant conclusions) via the ‘pmlr’ package in R version 2.15.3.

Whilst it was predicted that challenge appraisals would improve TT3 performance, no significant effects were observed. This is in contrast to the performances of the threat group, where both significant improvement ($\beta = 3.41$, 95% CI = 0.52, 8.54, $p = .018$) and significant deterioration ($\beta = 3.08$, 95% CI = 0.06, 8.23, $p = .046$) were more likely to occur than a neutral change during TT3 ($OR = 30.33$ and 21.67 respectively). Performances from past-oriented stress appraisal groups followed a uniform pattern. Participants in the harm/loss group were found to be significantly more likely to have their performance decline than stay neutral ($\beta = 3.15$, 95% CI = 0.46, 8.18, $p = .019$, $OR= 23.40$). Conversely, the benefit group produced an unequivocally positive performance change ($\beta = 5.13$, 95% CI = 1.90, 10.93, $p <.001$, $OR = 169.00$). As the control group acted as the counterbalance for odds ratio calculation, no outputs were calculated for its performance change.

Discussion

The purpose of Study 2 was to investigate the psychophysiological and performance influence of stress appraisals. Stress appraisals influenced psychological responses among athletes, with both challenge and benefit groups producing more positive secondary appraisals than their threat appraisal counterparts. In accordance with our hypotheses, stress appraisals also dictated the expression of coping behaviours with higher levels of task-oriented coping being associated with those engendered with challenge and benefit stress appraisals. This suggests that gain appraisals help people direct resources towards behaviours that facilitate performance. Finally, those in the threat group reported higher levels of harm/loss during TT3 than TT2, whilst both the challenge and benefit groups scored significantly higher in relation to benefit stress appraisals. With gain pre-competitive stress appraisals more likely to lead to gain post-competitive stress appraisals, coaches and athletes are encouraged to engender such mind-sets through techniques such as goal adjustment (Nicholls, Levy, Carson, Thompson, & Perry, 2016) in order to foster potentially higher levels of performance and well-being.

Our analyses showed no gender differences in performance, psychological, or neuroendocrine response. This contrasts with the extant psychological literature (Nicholls, Polman, Levy, Taylor, & Cobley, 2007), and suggests that males and females behave more similarly during stressful sporting competitions than previously found, thereby explaining the resultant lack of performance variance. This similarity may be explained by the findings of Kaiseler, Polman, and Nicholls (2013) and Swettenham, Eubank, Won, and Whitehead (2018), who discovered that the relationships between gender and coping within athletes may be moderated by appraisal. If this is true, males and females differ in their appraisal of a situation, rather than having gender-defined coping preferences. In an environment where stress appraisals were strictly engendered, it appears that the males and females who participated in this research experienced the same appraisals, and therefore employed the same coping behaviours. Regarding neuroendocrine response, our findings reflect the equivocal nature of the cortisol literature. With research studies finding both significant (van Paridon, Timmis, Nevison, & Bristow, 2017) and non-significant (Ceccato et al., 2015) differences in cortisol response between genders, this is an area clearly still not sufficiently understood (Chiodo et al., 2011).

We investigated the extent to which stress appraisals influenced neuroendocrine responses, as measured by salivary cortisol levels. In accordance with Lazarus' (1999, 2000) CMR theory of emotions, we hypothesised that gain stress appraisals would generate a reduced psychophysiological response in relation to loss stress appraisals. The results of our cortisol analyses did not fully support our hypotheses, though produced some novel findings nonetheless. Firstly, cortisol levels increased uniformly across all groups from pre-TT to immediate post-TT, indicating that cortisol secretion may be more sensitive to high intensity exercise than originally thought in previous research (Jacks et al., 2002). Further, moderate cortisol level increases were discovered during TT3 for both challenge and benefit groups, when compared to TT2. This increase was somewhat unexpected, yet inspection of the neuroendocrine response in sport literature indicates that the prospect of winning is also a physiologically stressful event (Suay et al., 1999). With a perceived chance of winning increasing the pressure on an athlete, this may have subsequently increased their anxiety and effort levels, as indexed by an increase in sympathetic nervous system activation (Cooke, Kavussanu, McIntyre, Boardley, & Ring, 2011). Conversely, significant variation in cortisol secretion was found between the loss stress appraisal groupings of threat and harm/loss. Firstly, a large effect was discovered in TP3 cortisol levels in the threat group. This might be a consequence of these athletes experiencing higher stress levels due to both their poor performance in comparison to others, as well as the uncertainty of whether they would finish the competition within the bottom two. This finding coincides with both our hypothesis, as well as previous findings (Epel et al., 2018; Harvey et al., 2010), where it has been shown that threat appraisals lead to increased and prolonged cortisol response due to a slower rise in sympathetic nervous system activity. This effect may be explained by the BPSM (Blascovich, 2008), which posits that both challenge and threat states cause increased sympathetic nervous system activation. This in turn leads to heightened cardiac output, whilst increased cortisol levels (via HPA axis activation) signal less emphasis to be placed on the parasympathetic-adrenomedullary system. In contrast, harm/loss participants displayed a large decrease in cortisol levels at both TP1 and TP3 on the final testing day. Physiological responses to performance is a complex process, dependent on an athlete's appraisal of the situation rather than the outcome itself. Indeed, the fear of losing may be more stressful than actually losing.

We examined the impact of the four different types of stress appraisal theorised by Lazarus (1999) on subsequent 16.1km TT performance, predicting that gain stress appraisal groups would improve from TT2 to TT3. Partial support for this hypothesis was observed. It should be noted that although we did not calculate odd ratios for the control group, none of the six participants produced a performance change above the 1.1% threshold, highlighting the replicability of the 16.1km TT task. However, there was also no significant performance change detected in the challenge group, which contradicts the performance assumptions of the BPSM (Blascovich, 2008). Such a result may potentially be linked to the challenge group's cortisol levels. Participants in the challenge group produced higher levels of cortisol at TP1 in TT2, despite no manipulation having taken place. With previous scholarly work (van de Pol, Kavussanu, & Ring, 2012) highlighting the juxtaposed enjoyably tense nature of competition, challenge group athletes may have been highly aroused for their first competitive TT. As such, any subsequent manipulation may not have had a large enough impact for significant performance improvement. Conversely, all benefit participants produced significantly faster times in TT3, compared to TT2. With benefit participants having received a concrete reassurance of their performance levels, as well as having an imminent and relevant goal, it is likely that their state confidence was enhanced because they were on target to reach their goal (Woodman & Hardy, 2003). Indeed, it has been suggested (Bray, Martin Ginis, Hicks, & Woodgate, 2008) that such a scenario is likely to free up attentional resources so participants could exclusively focus on maximising their cycling performance. Further, athletes with high levels of confidence have been suggested to be more proficient and effective in the use of their pool of resources (Hays, Thomas, Maynard, & Bawden, 2009).

Finally, we predicted that the TT performance of the threat and harm/loss stress appraisal participants would decline after their loss appraisal manipulations. The TT3 performance of nearly all participants in the harm/loss group deteriorated significantly, supporting our hypothesis. When taken into context with their decreased cortisol levels and increase in disengagement-oriented coping behaviours, it can be inferred that harm/loss participants simply stopped trying to attain their goals. Meanwhile, performances within the threat group varied greatly, with significant performance improvements and deterioration both found. Such intra-group variation may be caused by individual differences, with scholars (Turner et al., 2013) proposing that strong performance from participants exhibiting threat cardiovascular reactivity may be linked to high levels of self-efficacy. With high levels of cognitive anxiety and self-confidence significantly related to competitive sport performance (Woodman & Hardy, 2003), additional research into the psychophysiological and performance impact of threat stress appraisals within sport may prove fruitful. What is more, the investigation of constructs such as self-efficacy which underpin appraisal is of particular interest to researchers, as it may shed new light upon the appraisal-performance relationship. For example, researchers could employ a trait-state approach within a singular research design to examine how consistent personality constructs such as those within the "Big Five" (i.e. conscientiousness, agreeableness, neuroticism, openness, & extraversion; Goldberg, 1993) may impact subsequent appraisal, or alternatively how appraisal may override personality traits. Indeed, when one considers the negative impact personality types such as type D (Polman, Borkoles, & Nicholls, 2010) can have upon athletes (such as burnout and athlete withdrawal), state-based interventions could offer a positive and adaptive solution to athletes. Scholars within the literature have already begun to advocate a combined state-trait approach to athlete coping behaviours (Anshel & Si, 2008; Gaudreau & Miranda, 2010).

A number of limitations exist in this study. Firstly, due to the variation in participation times between participants, it was not possible to compare physiological response across groups. To further investigate cortisol response, diurnal variation should be controlled for by allocating groups according to natural cortisol levels (measured during pre-testing psychological screening), as well as testing at the exact same time of day. Further, the revised CICS (Gaudreau & Blondin, 2002) did not include the construct of 'distancing', as the items were deemed irrelevant to the task. Future research should look to develop tasks where distancing and social support are relevant and can therefore be measured. What is more, only limited significant emotional relationships between constructs were found. This may be due to the small sample used in this study. With the potential well-being and performance benefits of pleasant emotions suggested in models such as Broaden-and-Build theory (Fredrickson, 2001), future research would do well to assess their applicability in a sporting context. Finally, further measures of psychophysiological response (e.g., heart rate variability) are encouraged to provide a greater understanding of the stress process.

General Discussion

Whilst Lazarus (1999, 2000) suggested that appraisal is the key construct within his CMR theory of emotions, there has been limited research to examine all four primary appraisals, and thus, its full psychophysiological and performance influence. Indeed, until this study, athlete benefit and harm/loss appraisals had not been empirically examined within an experimental design. Stress appraisals positively predicted subsequent emotions, coping behaviours, and both subjective and objective goal attainment.

The psychophysiological and performance outputs of Study 2 also provide further context to the findings of Study 1, as well as to our understanding of the stress process. Differences were found across gain and loss stress appraisals, depending on the temporal orientation of the stress appraisal manipulation. In particular, cortisol spikes were discovered within both challenge and benefit stress appraisals following their gain state manipulations. The increase in physiological stress expressed by both groups in conjunction with the belief of imminent sporting success suggests that the existence of a physiological ‘success stress’ can be inferred. The potential existence of ‘success stress’ has been touched upon before (Suay et al., 1999), and moderate neuroendocrine response may aid athletic performance (Eubank, Collins, Lovell, Dorling, & Talbot, 1997), which may explain the unanimous performance improvement by benefit athletes. However, such a phenomena may also result in over arousal within athletes at critical sporting junctures, with severe cortisol levels impacting both performance (Elloumi et al., 2008) and bodily systems (Miller, Chen, & Zhou, 2007). These are key psychophysiological and performance implications for both athletes and scholars, with research into ‘success stress’ undoubtedly required. Regarding loss appraisals, the groupings of threat and harm/loss responded to their respective negative feedback in contrasting ways – the threat group exhibited a significant increase in cortisol secretion as their performance both significantly increased and decreased, whilst the harm/loss group unanimously withdrew from the situation in a psychophysiological and performance manner. These results demonstrate that temporal orientation of stress appraisals can dictate both physiological and performance response, and may even override stress appraisal valence. What is more, past-oriented stress appraisals are as autonomous and influential as future-oriented stress appraisals.

There are also further research implications stemming from the findings of both studies. The psychometrics findings provide support for not only Lazarus’ (1999, 2000) CMR theory of emotions, but also the supposition that appraisal is the key construct of the stress process. By engendering gain stress appraisals, coaches and practitioners may help protect their athletes from detrimental performance inhibitors resulting from threat stress appraisals such as spikes in cortisol levels (Elloumi et al., 2008). Indeed, with the manipulations imparted upon athletes within Study 2 as short as a few sentences, coaches must be cognisant of both the benefits and the losses that their athletes may incur via the cumulative effect of positive or negative feedback over months and years. Research which investigates the long-term effects of gain and loss stress appraisals, and/or the long-term effects of pleasant and unpleasant emotions would grant a greater insight into the profits and costs of such experiences.

Scholars may wish to address some of the limitations of this research in future studies. Firstly, the disposition of individual athletes is likely to have a degree of impact on subsequent athlete appraisals. Researchers (Seery, Blascovich, Weisbuch, & Vick, 2004) have suggested that a person's self-esteem may predict resultant challenge or threat stress appraisals. Future research could control for such variations through pre-experimental assessment. Secondly, whilst the cycle ergometer task was ecologically valid, past-oriented stress appraisals have only now been examined via a closed-skill task. Future research can build upon this work by investigating the impact of stress appraisals on a wide range of problem solving, open-skill, and team-based tasks. Such a diverse approach would also simultaneously widen the range of potential neuroendocrine and cardiovascular measures, which could include (but is not limited to) testosterone, quiet-eye duration, heart-rate variability, and resilience. Investigations such as these may also potentially reveal distinct neuroendocrine and/or cardiovascular reactions across past- and future-oriented appraisals.

Conclusions

In summary, the results of Study 1 provided support for Lazarus' (1999, 2000) CMR theory of emotions. These findings were then in turn partially supported by the psychophysiological protocol of Study 2, which also outlined the psychophysiological responses associated with each appraisal. This paper highlights the short-term impact of each of Lazarus' (1999, 2000) CMR stress appraisal groups, and provides a more thorough psychophysiological understanding of the stress process. In particular, Study 2 is the first of its kind to demonstrate the significant role temporal orientation in psychophysiological and performance response, rather than valence alone. Indeed, comparison of the threat and harm/loss stress appraisal groups suggest that the fear of defeat may be physiologically more stressful than losing itself. Further, cortisol spikes within both the benefit and challenge stress appraisal group's highlight the inherent physiological stress involved with winning. By providing athletes with goal relevant positive feedback that is temporally imminent, stakeholders may successfully engender a benefit stress appraisal. From this, athletes may benefit cognitively, somatically, and from a performance perspective.

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Table 1. Appraisal group cortisol levels (ng/ml) and subsequent time point effects

Group	Time Point	TT2 Mean and SD (ng/ml)	TT3 Mean and SD (ng/ml)	*p* Value	Effect Size (*g*)
Challenge	TP1	37.47 ± 22.31	37.88 ± 13.50	.95	0.02
Challenge	TP2	54.17 ± 17.42	54.62 ± 19.70	.96	0.02
Challenge	TP3	44.75 ± 10.89	53.09 ± 18.03	.39	0.52
Threat	TP1	12.87 ± 8.51	12.87 ± 10.92	.77	0.19
Threat	TP2	49.53 ± 24.84	45.32 ± 19.09	.66	0.18
Threat	TP3	45.74 ± 13.95	64.45 ± 23.14	.06	0.90
Benefit	TP1	16.01 ± 12.70	24.17 ± 19.77	.24	0.45
Benefit	TP2	31.59 ± 20.79	37.76 ± 27.03	.51	0.24
Benefit	TP3	35.46 ± 23.37	42.17 ± 18.47	.49	0.29
H/L	TP1	22.6 ± 21.49	9.3 ± 5.94	.60	0.78
H/L	TP2	35.48 ± 19.44	38.81 ± 12.76	.72	0.19
H/L	TP3	51.7 ± 27.22	34.63 ± 12.79	.08	0.74
Control	TP1	13.1 ± 13.93	21.38 ± 16.50	.24	0.50
Control	TP2	21.99 ± 8.79	30.34 ± 16.94	.38	0.57
Control	TP3	39.63 ± 15.6	41.46 ± 22.40	.85	0.09

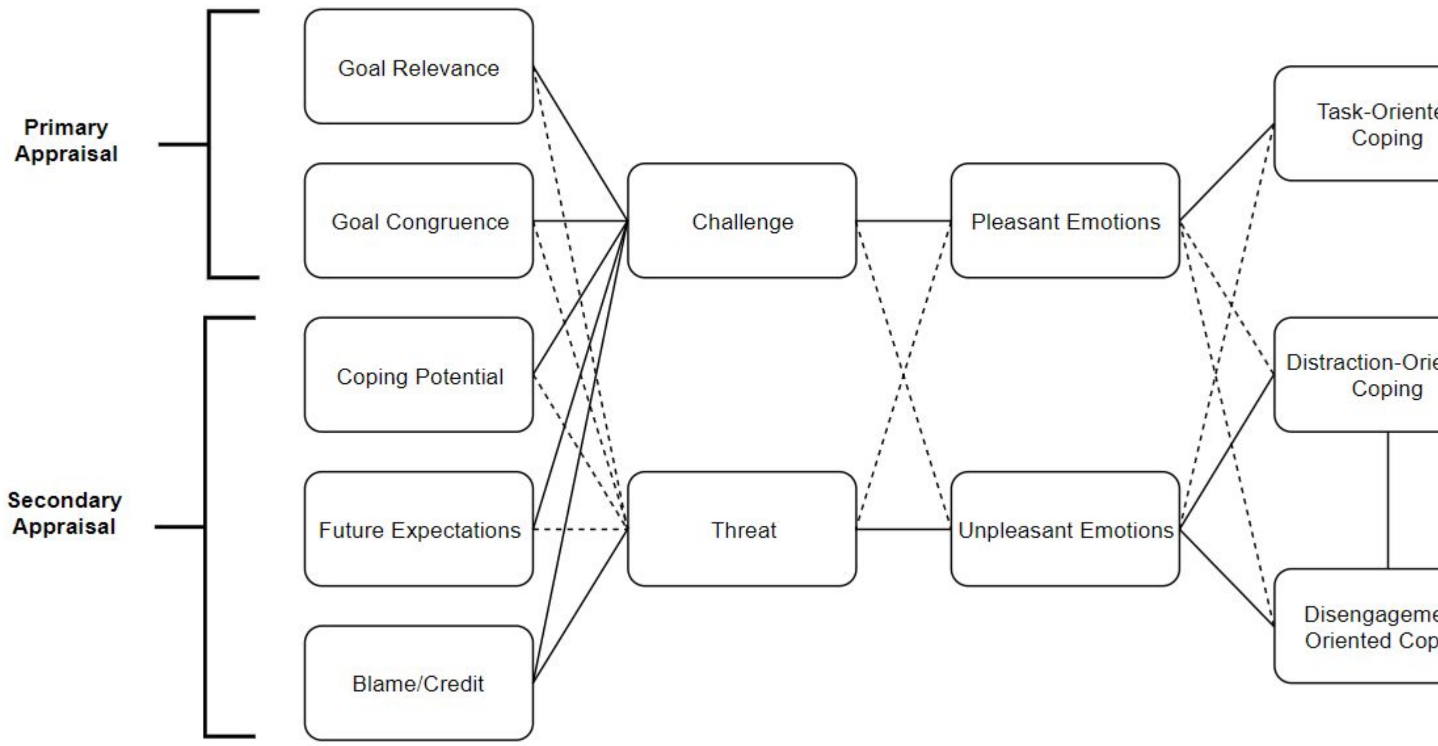
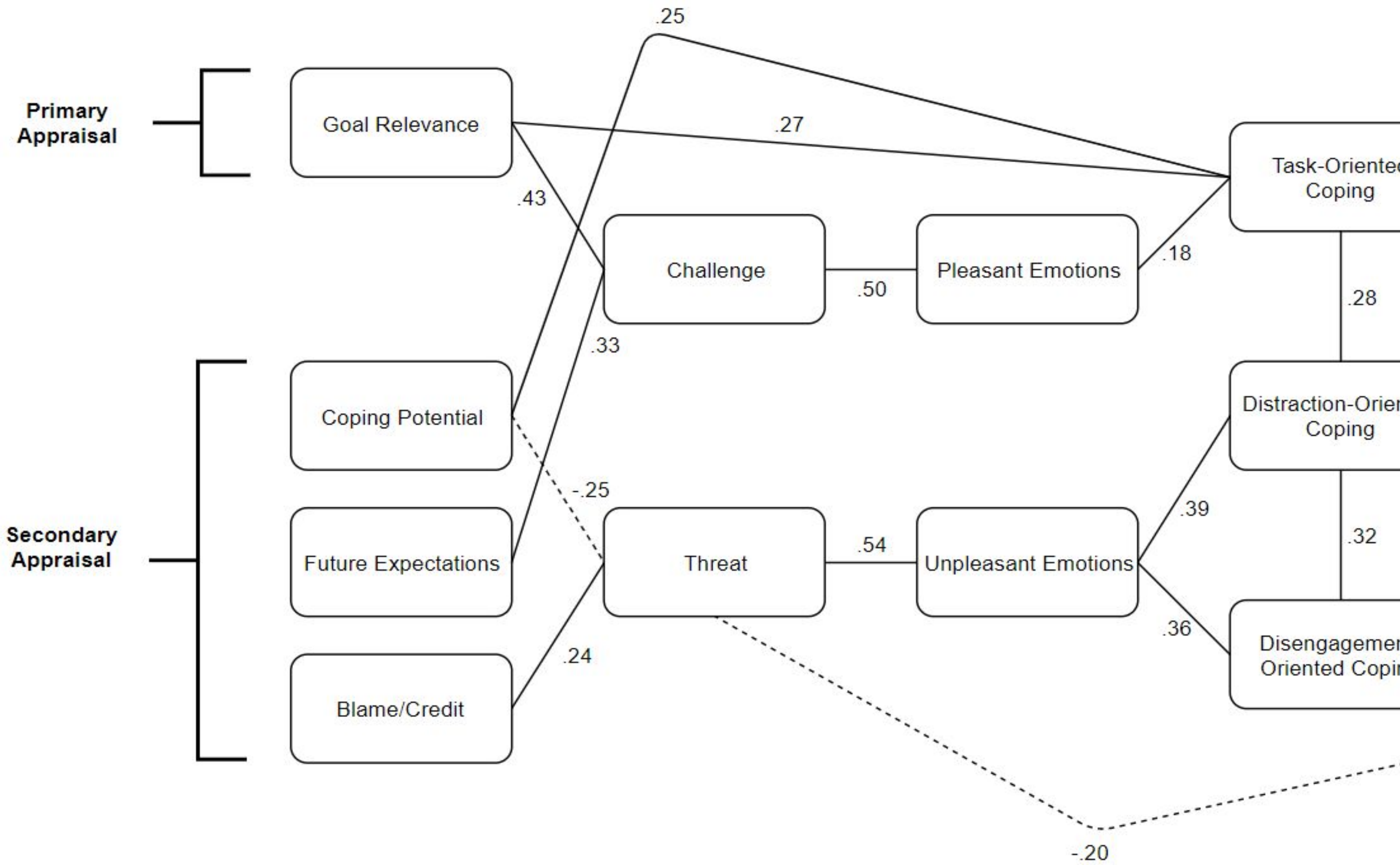


Figure 1

Hypothesised Model

Positive Path

Negative Path



Primary Appraisal
Secondary Appraisal
Goal Relevance
Coping Potential
Future Expectations
Blame/Credit
Challenge
Threat
Pleasant Emotions
Unpleasant Emotions
Task-Oriented Coping
Distraction-Orien Coping
Disengagemen Oriented Copi
.25
.27
.43
.50
.18
.28
.33
-.25
.54
.39
.32
.36
.24
-.20

Figure 2

Final, parsimonious model with standardized parameter estimates.

Positive Path

Negative Path