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CHALLENGE AND THREAT STATES IN MOTIVATED PERFORMANCE

SITUATIONS

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ABSTRACT

The biopsychosocial model (BPSM) offers a potential explanation for why individuals perform differently in pressurised motivated performance situations (e.g., sporting competitions). The aim of this thesis was to test the predictions of the BPSM to further our understanding of performance variability under pressure. Specifically, the BPSM suggests that individuals' respond to a pressurised situation with either a challenge or threat state, with the former resulting in better performance. Three experimental studies were conducted to test this proposition and examine the immediate effect of challenge and threat states on the performance of laboratory-based motor tasks and real competition. Across all studies, a challenge state resulted in, or was associated with, superior performance. Importantly, this finding was consistent across different samples and research designs. In two of these studies, the proposed mechanisms (emotional, attentional, and behavioural) through which challenge and threat states might influence performance were also investigated. In both studies, a challenge state was associated with more favourable emotions (less anxiety and more facilitative interpretations) and attention (longer quiet eye durations and less conscious processing). Furthermore, in one study, a challenge state was also associated with more effective behaviour (lower muscle activity and superior clubhead movements). Crucially, mediation analyses indicated that challenge and threat states influenced performance by impacting the quality of task-related movements. The BPSM predicts that a range of factors influence whether an individual responds to a pressurised situation with a challenge or threat state (psychological and physical danger, familiarity, uncertainty, required effort, skills, knowledge and abilities, and the availability of support). In a fourth experimental study, two of these antecedents

were examined; perceived required effort and support availability. In this study, although perceptions of support availability had limited impact, perceptions of low required effort led to a challenge state and better performance than perceptions of high required effort.

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PREFACE

This thesis includes published manuscripts. The data from this thesis has also been presented at various Institutional, National, and International Conferences. The details of all outputs related to this thesis are below. Furthermore, additional published manuscripts and conference presentations written and presented throughout the development of this thesis are outlined in Appendix 1.

Articles

Moore, L.J., Vine, S.J., Wilson, M.R., & Freeman, P. (2014). Examining the antecedents of challenge and threat states: The influence of perceived required effort and support availability. *International Journal of Psychophysiology*, *93*, 267-273. doi:10.1016/j.ijpsycho.2014.05.009.

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

Moore, L.J., Vine, S.J., Wilson, M.R., & Freeman, P. (2012). The effect of challenge and threat states on performance: An examination of potential mechanisms. *Psychophysiology*, *49*, 1417-1425. doi:10.1111/j.1469-8986.2012.01449.x.

McGrath, J.S., **Moore, L.J.**, Wilson, M.R., Freeman, P., & Vine, S.J. (2011). Challenge and threat states in surgery: Implications for surgical performance and training. *British Journal of Urology International*, *108*, 795-796. doi:10.1111/j.1464-410X.2011.10558.x.

Published Abstracts and Conference Presentations

Moore, L.J., Vine, S.J., Wilson, M.R., & Freeman, P. (2014, April). The influence of perceived required effort and support availability on challenge and threat states and subsequent motor performance. *Paper presented at the Postgraduate Research Showcase 2014, University of Exeter, England.*

Moore, L.J., Wilson, M.R., Vine, S.J., Coussens, A.H., & Freeman, P. (2013, April). Champ or chump? Challenge and threat states during pressurized competition. *Paper presented at the British Psychological Society, Expertise and Skill Acquisition Network Annual Meeting, English Institute of Sport, Bisham Abbey, England.*

Moore, L.J., Vine, S.J., Wilson, M.R., & Freeman, P. (2012, December). The impact of challenge and threat states on the motor performance of experienced golfers. *Paper presented at the Sport and Health Science Postgraduate Poster Event, University of Exeter, England.*

Moore, L.J., Vine, S.J., Wilson, M.R., & Freeman, P. (2012, July). The effect of challenge and threat states on motor task performance: An examination of potential underlying mechanisms. *European College of Sport Science Annual Congress, Bruges, Belgium, Book of Abstracts.*

As all of the studies in this thesis are published, each chapter has an extended literature review adapted from the published article. Thus, some repetition may be present regarding the description of theories and previous research.

CHAPTER 1: LITERATURE REVIEW

1.1 Introduction

"Pressure can burst a pipe, or pressure can make a diamond." (Robert Horry)

In modern-day life, individuals are required to perform important tasks in highly pressurised situations under extreme stress (e.g., exams, presentations, job interviews, and sporting competitions). However, as the above quote suggests, pressure and the situational stress it provokes, can have different effects on individuals. While some individuals respond negatively and perform poorly (i.e., choking; Mesagno & Hill, 2014), others respond positively and perform well (i.e., clutch performance; Otten, 2009). Indeed, there have been many high profile examples of such performance variability in response to pressure. For instance, Rory McIlroy's spectacular collapse in the final round of the 2011 Masters Golf tournament in Augusta is a classic example of choking in a highly pressurised sporting context. Conversely, Captain Sullenberger's heroic decision to land US Airways Flight 1549 on the Hudson River in order to save the lives of all crew members and passengers in 2009 is a prime example of clutch performance in an extremely stressful aviation scenario.

It seems that for every example of an individual who did not cope with the demands of a highly pressurised situation, there is an example of an individual who did. This thesis examines the possible reasons underpinning such performance variability under pressure using the biopsychosocial model (BPSM; Blascovich, 2008a) of challenge and threat as a theoretical framework. It is hoped that by testing the predictions of the BPSM, the identification of individuals who are likely to perform well under pressure and those that may need an intervention to help them cope and perform better in a pressurised

situation can be improved. In order to provide an empirical background for the studies within this thesis, the following literature review outlines the central tenets of the BPSM and previous validation research supporting the models main predictions. Next, previous research that has examined the relationship between challenge and threat states and task performance is reviewed. Subsequently, the potential mechanisms through which challenge and threat states might influence performance are detailed using the propositions of various authors and recent theories (e.g., Theory of Challenge and Threat States in Athletes; Jones, Meijen, McCarthy, & Sheffield, 2009). Next, the antecedents proposed by the BPSM to influence challenge and threat states are described. Finally, in the light of the reviewed literature, the aims of this thesis are outlined as well as how this thesis extends previous research.

1.2 Biopsychosocial Model

Over the last 20 years the BPSM of challenge and threat has become an increasingly popular theoretical framework to explain individuals' reactions to stress (Blascovich, 2008a; Blascovich, 2014; Blascovich & Mendes, 2000; Blascovich & Tomaka, 1996). The BPSM applies to motivated performance situations, in which individuals must actively perform instrumental responses (cognitive and/or behavioural) to attain an important and self-relevant goal. Example situations include tests, job interviews, competitions, public speaking, and social interactions. These situations are frequently experienced by most individuals and are highly important and potentially stressful as they often have meaningful consequences such as university admission, job offers, trophies, embarrassment, and finding romantic partners (Seery, 2011). Thus, individuals are usually actively engaged in these situations and the tasks performed within

them. The BPSM contends that how individuals perform in motivated performance situations is determined by a series of psychological processes and evaluations that lead to distinct patterns of physiological responses (Seery, 2013). These processes and responses are described in the following sections (see Figure 1.1 for an overview of the BPSM).

1.2.1 Psychological Processes

The psychological component of the BPSM is underpinned by Lazarus's cognitive appraisal theory (Lazarus, 1991, 1999; Lazarus & Folkman, 1984). According to Lazarus and colleagues, how individuals respond to a stressful situation is shaped by their cognitive appraisals. There are two types of appraisal: primary and secondary. Primary appraisals assess whether a situation is relevant to one's well-being, with a situation deemed irrelevant, benign-positive, or stressful. Stressful appraisals can take three forms: harm/loss, threat, and challenge. While harm/loss appraisals refer to psychological damage the individual has already experienced, threat appraisals refer to anticipated harms or losses, and challenge appraisals refer to potential for mastery or gains. Secondary appraisals assess available coping resources and options that can be employed in response to the situation. Together, these primary and secondary appraisals determine how an individual reacts to a stressful situation. Importantly, these appraisals can change in the light of new information relating to the situation, a process termed reappraisal (Lazarus & Folkman, 1984).

In Lazarus's conceptualisation, challenge and threat are therefore considered two distinct types of primary appraisal that contribute to how a

Figure 1.1 An overview of the biopsychosocial model of challenge and threat.

Psychological Processes

Physiological Responses

Motivated performance situation

Danger, familiarity, required effort, skills, knowledge, abilities, and available support

Demands and resource evaluations

Resources match or exceed demands

Demands exceed resources

Challenge

Threat

SAM activation

SAM and PAC activation

Increased HR
Increased CO
Decreased TPR

Increased HR

No change or decreased CO

No change or increased TPR

Good task performance

Poor task performance

Note: SAM = sympathetic-adrenomedullary; PAC = pituitary-adrenocortical; HR

= heart rate; CO = cardiac output; TPR = total peripheral resistance

potentially stressful situation is viewed (Lazarus & Folkman, 1984). In contrast, in the BPSM, challenge and threat represent the end result of what corresponds to Lazarus's primary and secondary appraisals (Seery, 2011). Thus, according to the BPSM, whether an individual judges a stressful motivated performance situation as a challenge or threat is determined by their evaluations of situational demands (i.e., primary appraisal) and personal coping resources (i.e., secondary appraisal). More specifically, individuals who believe that they have sufficient resources to cope with the demands of a situation, evaluate the situation as a challenge. Conversely, individuals who judge that they have insufficient resources to cope with situational demands, evaluate the situation as a threat (see Figure 1.1; Seery, 2011). Blascovich and colleagues prefer to use the term 'evaluation' rather than the label 'appraisal' employed by Lazarus and colleagues, as they propose that the demand/resource evaluation process is more unconscious and automatic than conscious and deliberate (Blascovich, 2008a).

Consistent with the propositions of cognitive appraisal theory (Lazarus & Folkman, 1984), the BPSM argues that the demand/resource evaluation process is dynamic and that evaluations continuously fluctuate during motivated performance situations (Blascovich, 2008a; Seery, 2011). Thus, while individuals might evaluate a stressful situation as a threat at first, this might alter after a few minutes, leading individuals to re-evaluate the situation as less threatening or even challenging, and vice versa. Indeed, despite their discrete labels, it should be noted that the BPSM does not consider challenge and threat as dichotomous states. Instead, challenge and threat are viewed as two anchors of a single bipolar continuum such that relative differences in challenge and threat (i.e., greater vs. lesser challenge or threat) are both possible and

meaningful (Seery, 2011). This is in contrast with the view of Lazarus and colleagues who considered challenge and threat as separate constructs that could occur simultaneously (Lazarus, 1999). Thus, challenge and threat were not viewed as poles of a single bipolar continuum in the cognitive appraisal theory (Lazarus & Folkman, 1984).

1.2.2 Physiological Responses

In order to explain how the above psychological processes influence physiological responses, the BPSM draws upon Dienstbier's (1989) theory of physiological toughness. Based mostly on animal research, Dienstbier noted two patterns of neuroendocrine and cardiovascular responses during potentially stressful performance situations (e.g., gathering food near predators): one among animals who thrived during and after these situations (termed physiological toughness), and another for animals who did not (termed physiological weakness). According to Dienstbier, both patterns involve sympathetic-adrenomedullary activation causing the release of catecholamines (epinephrine and norepinephrine). This results in increased myocardial contractility indexed by increases in heart rate (number of heart beats per minute), dilation of the blood vessels marked by reductions in total peripheral resistance (net constriction versus dilation in the arterial system), and increased blood flow indexed by increases in cardiac output (amount of blood in litres pumped by the heart per minute). Importantly, the pattern of physiological weakness also involves pituitary-adrenocortical activation, prompting the release of cortisol. Subsequently, this attenuates the effects of sympathetic-adrenomedullary activation, and can even lead to increases in total peripheral resistance and decreases in cardiac output (Dienstbier, 1989).

Both sympathetic-adrenomedullary and pituitary-adrenocortical activation mobilise energy reserves so, if necessary, physical activity can be performed in a stressful performance situation. The former, results in a fast and short-lived spike of energy, due to the release of catecholamines that enter the bloodstream quickly and have a half-life of only a few minutes. In contrast, the latter, causes a slow and more prolonged release of energy, because the cortisol enters the bloodstream slowly and has a half-life of over an hour (Seery, 2013). Subsequently, due to the expedient delivery of more energy to the brain and muscles, Dienstbier argued that the pattern of physiological toughness is associated with better task performance in potentially stressful situations than the pattern of physiological weakness. Furthermore, as prolonged and repeated pituitary-adrenocortical activation can lead to detrimental health outcomes (e.g., immune function; Blascovich, 2008b), Dienstbier considered the pattern of physiological toughness better for long-term survival than the pattern of physiological weakness. Finally, Dienstbier suggested that the pattern of physiological toughness is linked with a tendency to perceive that one can cope with a stressful situation, a perception consistent with a challenge evaluation (i.e., personal coping resources match or exceed situational demands; Dienstbier, 1989; Seery, 2013).

Blascovich and colleagues mapped the patterns of physiological toughness and weakness outlined by Dienstbier (1989) onto challenge and threat evaluations, respectively (Blascovich, 2008b). Thus, according to the BPSM, individuals who evaluate that they have sufficient resources to meet the demands of the motivated performance situation (challenge), exhibit the cardiovascular pattern of physiological toughness (i.e., increases in heart rate and cardiac output, and a decrease in total peripheral resistance). In contrast,

individuals who evaluate that they do not possess the resources required to cope with the demands of the situation (threat), display the cardiovascular pattern of physiological weakness (i.e., an increase in heart rate, little change or a decrease in cardiac output, and little change or an increase in total peripheral resistance; Blascovich, 2014). Thus, both challenge and threat states are characterised by increases in heart rate from a resting baseline state (i.e., reactivity), a cardiovascular response that is said to reflect active engagement with the task (a pre-requisite for challenge and threat states; Seery, 2011). A challenge state is characterised by relatively larger increases in cardiac output and decreases in total peripheral resistance compared to a threat state (see Figure 1.1; Blascovich, 2008a). Importantly, this cardiovascular response is considered more efficient for energy mobilisation and action, as blood flow (and therefore glucose and fatty acids) to the brain and muscles is increased and less restricted (Dienstbier, 1989; Seery, 2011). This cardiovascular pattern is comparable to the body's response during aerobic exercise.

Although challenge and threat states can be assessed using subjective measures of demand/resource evaluations, Blascovich and colleagues prefer to measure these states via the above cardiovascular indices (Blascovich, 2008a). This is because these markers can be continuously and covertly recorded online prior to and during the motivated performance situations, making them sensitive to changes in challenge and threat over time and impervious to the biases associated with self-report measures (e.g., social desirability bias; Blascovich, 2008a; Seery, 2013). Furthermore, it has been argued that because the demand/resource evaluation process is relatively unconscious and automatic, individuals may not be able to accurately reflect upon and report these evaluations (Seery, 2011). It has also been suggested that the process of

interrupting individuals and directing their attention towards a self-report measure could itself influence demand/resource evaluations and thus challenge and threat states (Seery, 2013). However, despite their limitations, it should be noted that self-report measures offer an expedient alternative to cardiovascular indices and have been shown to closely corroborate with the objective markers of challenge and threat states during validation studies (Tomaka, Blascovich, Kelsey, & Leitten, 1993; Zanstra, Johnston, & Rasbash, 2010).

1.2.3 Validation Research

The predictions of the BPSM and the cardiovascular markers of challenge and threat were validated in a series of correlational and experimental studies (Tomaka, Blascovich, Kelsey, & Leitten, 1993; Tomaka, Blascovich, Kibler, & Ernst, 1997). These empirical studies involved laboratory-based, non-metabolically demanding, motivated performance situations that required participants to perform a mental arithmetic (i.e., verbal serial subtraction) task. In all of these studies electrocardiographic, impedance cardiographic, and hemodynamic recording equipment was used to assess cardiovascular responses during resting baseline (i.e., before participants received task instructions) and throughout task performance. Reactivity scores were calculated by subtracting the values during the final minute of baseline from the values during the tasks. Furthermore, in all of these studies demand and resource evaluations were assessed prior to task performance, once participants had received task instructions. A cognitive appraisal ratio was calculated by dividing evaluated demands by resources, with a ratio less than one reflecting challenge (i.e., resources match or exceed demands) and a ratio greater than one indicating threat (i.e., demands exceed resources).

Tomaka and colleagues conducted three separate correlational studies to explore the association between subjective demand/resource evaluations and cardiovascular responses during mental arithmetic tasks (Tomaka et al., 1993). In all of these studies, two groups (challenge and threat) were created using a median split on the cognitive appraisal ratio data. In the first study, the results revealed that the challenge group (ratio ≤ 1; resources match or outweigh demands) displayed significantly greater physiological activation (i.e., pulse transit time) compared to the threat group (ratio > 1; demands outweigh resources). In the second and third studies, more sophisticated cardiovascular measures were employed. The results of these studies were identical and supported the predictions of the BPSM. Specifically, the challenge groups exhibited significantly greater cardiac output reactivity and lower total peripheral resistance reactivity than the threat groups. In addition, the challenge groups reported experiencing less stress during the task than the threat groups (Tomaka et al., 1993).

Although the correlational studies offered initial support for the validity of the cardiovascular markers of challenge and threat, these studies relied heavily on the self-selection of participants into challenge and threat groups. Thus, Tomaka and colleagues conducted three experimental studies to better explore the causal relationship between demand/resource evaluations and these cardiovascular indices (Tomaka et al., 1997). In the first study, participants performed a mental arithmetic task after randomly receiving one of two instructional sets designed to manipulate participants into either a challenge or threat state. While the challenge instructions emphasised that participants should think of the task as a challenge to be met and that they are capable of meeting that challenge, the threat instructions emphasised that the task was

mandatory and that their performance would be evaluated. The results indicated that the challenge group evaluated the task as a challenge (ratio ≤ 1; resources match or outweigh demands) and the threat group evaluated it as a threat (ratio > 1; demands outweigh resources). Moreover, consistent the predictions of the BPSM, the challenge group displayed significantly greater cardiac output reactivity and lower total peripheral resistance reactivity than the threat group.

In the second and third studies, Tomaka and colleagues examined the possibility of a reversal of causality, and whether challenge and threat cardiovascular patterns influenced demand/resource evaluations (Tomaka et al., 1997). In study two, cardiovascular patterns were manipulated via aerobic exercise by having participants either cycle on an ergometer at a moderate workload (to elicit a challenge cardiovascular response) or sit stationary on the ergometer (to mimic the threat cardiovascular response). In study three, cardiovascular patterns were manipulated by getting participants to immerse their hand in either warm (to promote a challenge cardiovascular response) or cold (to encourage a threat cardiovascular response) water. In both studies, during the manipulation (i.e., while on the bike or with hand immersed in the water), participants reported demand and resource evaluations for an upcoming mental arithmetic task. The results revealed that demand/resource evaluations did not differ across the various manipulations, suggesting that evaluations were not a product of divergent cardiovascular patterns. Instead, collectively, the results of these experimental validation studies indicate that the opposite is true, demand/resource evaluations impact upon subsequent cardiovascular responses.

Following this validation research, the cardiovascular markers of challenge and threat have been successfully employed in studies examining various psychological theories (Blascovich, 2008a). These have included theories relating to justice beliefs (Tomaka & Blascovich, 1994), religious beliefs (Weisbuch-Remington, Mendes, Seery, & Blascovich, 2005), self-esteem (Lupien, Seery, & Almonte, 2012; Seery, Blascovich, Weisbuch, & Vick, 2004), social comparison (Cleveland, Blascovich, Gangi, & Finez, 2012; Mendes, Blascovich, Major, & Seery, 2001), stigma (Blascovich, Mendes, Hunter, Lickel, & Kowai-Bell, 2001), stereotype threat (Vick, Seery, Blascovich, & Weisbuch, 2008), defensive pessimism (Seery, West, Weisbuch, & Blascovich, 2008), coalition formation (Van Beest & Scheepers, 2013), social identity (Derks, Scheepers, Van Laar, & Ellemers, 2011; Scheepers, 2009; Scheepers, Saguy, Dovidio, & Gaertner, 2014), social power (Akinola & Mendes, 2013; Scheepers, De Wit, Ellemers, & Sassenberg, 2012), morality framing (Does, Derks, Ellemers, & Scheepers, 2012), intragroup conflict (De Wit, Scheepers, & Jehn, 2012; Kouzakova, Harinck, Ellemers, & Scheepers, 2014), resilience (Murray, Lupien, & Seery, 2012; Seery, Leo, Lupien, Kondrak, & Almonte, 2013), goal orientations (Chalabaev, Major, Cury, & Sarrazin, 2009), emotional control (Mauss & Butler, 2010), group identification (Eliezer, Major, & Mendes, 2010), group dynamics (Frings, Hurst, Cleveland, Blascovich, & Abrams, 2012), leadership (Hoyt & Blascovich, 2010), attributional ambiguity (Mendes, McCoy, Major, & Blascovich, 2008), social anxiety disorder (Shimizu, Seery, Weisbuch, & Lupien, 2012), and child maltreatment (McLaughlin, Sheridan, Alves, & Mendes, 2014). For example, Blascovich and colleagues conducted a study in which the BPSM was used to examine social facilitation effects (Blascovich, Mendes, Hunter, & Salomon, 1999). The results of this study demonstrated that

when participants were asked to perform a well-learned task in front of an audience, participants displayed a challenge cardiovascular response. In contrast, when participants were asked to perform a novel task in front of an audience, participants exhibited a threat cardiovascular response. While not validation studies, this substantial research does offer further support for the cardiovascular markers of challenge and threat states proposed by the BPSM (Blascovich, 2008a).

1.2.4 Performance Consequences

According to the BPSM, task performance is better during a motivated performance situation when the situation is evaluated as a challenge rather than a threat (Blascovich, 2008a). The first study to offer support for this prediction was conducted by Tomaka and colleagues (study 2, 1993). In a correlational study, these authors examined the relationship between subjective demand/resource evaluations and performance during a mental arithmetic task. This task required the participants to perform verbal serial subtractions from the value 2,737 by intervals of 7. Tomaka and colleagues created two experimental groups (challenge and threat) using a median split on the cognitive appraisal ratio data. In line with the prediction of the BPSM, the results revealed that the challenge group (ratio ≤ 1; resources match or outweigh demands) outperformed the threat group (ratio > 1; demands outweigh resources). More specifically, the challenge group reported performing better (perceived performance) and verbalised more subtractions and made more correct subtractions (actual performance) than the threat group (Tomaka et al., 1993).

Since this initial experiment, more studies have provided evidence of the association between demand/resource evaluations and subjective and objective

performance (Drach-Zahavy & Erez, 2002; Feinberg & Aiello, 2010; White, 2008; Williams & Cumming, 2012). For example, O'Connor and colleagues asked participants to report evaluated demands and resources (via cognitive appraisal ratio) before performing a complex negotiation task. The results revealed that evaluating the task as a threat was associated with poorer negotiating performance (i.e., lower quality deals; study 1, O'Connor, Arnold, & Maurizio, 2010). In another study, Gildea and colleagues examined if demand/resource evaluations prior to a period of training on a simulated aviation task predicted performance during baseline, training, and post-training trials. After creating two groups (challenge and threat) using a median split on the cognitive appraisal ratio data, the authors found that the challenge group achieved higher scores on the task throughout training as well as during baseline and post-training (retention, transfer, and secondary task) trials (Gildea, Schneider, & Shebilske, 2007). Taken together, this research supports the BPSM's contention that a challenge evaluation should lead to better task performance than a threat evaluation.

As well as looking at the association between demand/resource evaluations and task performance, a number of studies have investigated the relationship between challenge and threat cardiovascular patterns and performance. Among the first was the predictive study conducted by Blascovich and colleagues that examined if the cardiovascular markers of challenge and threat predicted future athletic performance (Blascovich, Seery, Mugridge, Norris, & Weisbuch, 2004). In this study, six months before the start of the season, college baseball and softball players delivered a sport-relevant speech while cardiovascular responses were recorded. Offensive baseball and softball statistics (i.e., runs created, batting averages etc.) were then recorded during

the subsequent season. The results revealed that players who exhibited a challenge cardiovascular response (i.e., relatively higher cardiac output and lower total peripheral resistance) during the speech, performed better during the subsequent season, creating more runs, than those who displayed a threat cardiovascular response. The results of this study have since been replicated in relation to academic performance (Seery, Weisbuch, Hetenyi, & Blascovich, 2010). Indeed, Seery and colleagues found that students who exhibited a challenge cardiovascular response to an academic-relevant speech, performed better during the subsequent academic term (i.e., higher points total) than students who displayed a threat cardiovascular response.

Turner and colleagues have since extended these predictive studies through the addition of baseline conditions (Turner, Jones, Sheffield, & Cross, 2012; Turner, Jones, Sheffield, Slater, Barker, & Bell, 2013). In two studies, these authors examined if the cardiovascular markers of challenge and threat were related to performing better or worse than baseline on competitive cognitive (i.e., stroop test) and motor (i.e., netball shooting) tasks. In both studies, the results revealed that a challenge cardiovascular response predicted greater improvements in accuracy from baseline than a threat cardiovascular response (Turner et al., 2012). Furthermore, in another study, these authors investigated if the cardiovascular indexes of challenge and threat could predict the performance of elite cricketers during a pressurised batting test 24 hours later. Once again a challenge cardiovascular response predicted superior batting performance (Turner et al., 2013). In addition to supporting the prediction of the BPSM regarding the effects of challenge and threat states on performance, the predictive studies also offer further validation for the cardiovascular markers of challenge and threat states proposed by the model.

1.3 Potential Underlying Mechanisms

The aforementioned research suggests that while a challenge state is associated with good task performance, a threat state is associated with poor task performance. However, despite these findings, limited research has examined the potential mechanisms through which challenge and threat states might influence performance. Although the BPSM offers no predictions regarding precisely how challenge and threat states impact performance, Blascovich and colleagues have discussed some possible mechanisms (e.g., Blascovich et al., 2004). Furthermore, a recent theory that applied the core assumptions of the BPSM to sport, the Theory of Challenge and Threat States in Athletes (TCTSA; Jones et al., 2009), discusses potential mechanisms through which challenge and threat states might operate. These mechanisms can be divided into three broad categories: emotional, attentional, and behavioural. In the following sections these proposed underlying mechanisms are outlined in turn.

1.3.1 Emotional Mechanisms

According to the TCTSA, the emotional response emanating from a challenge state is said to be more favourable than the response arising from a threat state (Jones et al., 2009). Specifically, while both positive and negative emotions are said to be experienced during a challenge state, only negative emotions are proposed to be experienced during a threat state. Moreover, although emotions are said to be interpreted as facilitative for performance in a challenge state, emotions are proposed to be viewed as debilitative in a threat state (Jones et al., 2009; Skinner & Brewer, 2004). Recent research examining these propositions have revealed mixed results. Indeed, correlational studies

have revealed weak and inconsistent relationships between challenge and threat cardiovascular responses and emotions (Meijen, Jones, McCarthy, Sheffield, & Allen, 2013a; Meijen, Jones, Sheffield, & McCarthy, 2013b; Turner et al., 2012; Turner et al., 2013). However, most experimental studies have offered stronger support for the above predictions (Quested, Bosch, Burns, Cumming, Ntoumanis, & Duda, 2011; Turner, Jones, Sheffield, Barker, & Coffee, 2014; Williams & Cumming, 2012). For example, Williams and colleagues found that a challenge imagery script caused athletes to report experiencing less cognitive anxiety and more facilitative interpretations of cognitive and somatic anxiety, than a threat imagery script (Williams, Cumming, & Balanos, 2010).

Positive and negative emotions are typically associated with successful and unsuccessful performance, respectively (Craft, Magyar, Becker, & Feltz, 2003; McCarthy, 2011). Indeed, recent research has supported this dichotomy (Lane et al., 2010). For example, Nicholls and colleagues used a path analysis model to examine the relationship between 557 athletes' emotions and subjective performance. These authors found that while positive emotions (i.e., excitement and happiness) were positively associated with performance, negative emotions (i.e., anxiety, dejection, and anger) were negatively associated with performance (Nicholls, Polman, & Levy, 2012). In addition, facilitative interpretations of emotions generally predict more successful performance than debilitative interpretations (Hanton, Neill, & Mellalieu, 2008; Mellalieu, Hanton, & Fletcher, 2006). For example, Thomas and colleagues found that an intervention that successfully altered elite hockey players' interpretations of anxiety, so they were more facilitative for performance, resulted in improvements in competitive performance (Thomas, Maynard, &

Hanton, 2007). Taken together, the above research suggests that a challenge state might result in superior performance compared to a threat state by promoting more favourable emotional responses (i.e., higher positive and lower negative emotions) and interpretation of emotions (i.e., more facilitative for performance).

1.3.2 Attentional Mechanisms

According to the predictions of the TCTSA and the suggestions of various authors, attention may be more effective during a challenge state than a threat state. Specifically, attention is said to be focused on task-relevant cues during a challenge state, but towards task-irrelevant cues, or controlling one's actions, in a threat state (Blascovich et al., 2004; Jones et al., 2009). To date, no research has investigated these assumptions. However, considerable research has demonstrated that directing attention inward to consciously control the execution of autonomous motor skills is an ineffective use of attention that can have negative consequences for the performance of experienced individuals, particularly under conditions of elevated pressure (Masters & Maxwell, 2008; Wulf, 2013). For instance, Beilock and colleagues asked experienced golfers to perform golf putts under skill-focused conditions designed to direct conscious attention towards the step-by-step execution of the putting stroke (i.e., verbally indicate the end of the putting stroke). The results revealed that the golfers' putting performance was significantly worse in this condition than a practice condition (Beilock, Carr, MacMahon, & Starkes, 2002).

Furthermore, an abundance of research using eye-tracking technology to objectively measure attention has demonstrated that effective attention in a variety of tasks is characterised by longer quiet eye durations (Mann, Williams,

Ward, & Janelle, 2007). Indeed, longer quiet eye durations have been shown to underpin higher levels of expertise and proficiency in a wide range of tasks. For example, Vickers (1992) found that expert golfers had longer quiet eye durations than non-expert golfers when performing golf putts, and that successful putts were associated with longer quiet eye durations than unsuccessful putts. When lengthened, the quiet eye - defined as the final fixation towards a relevant target before movement initiation (Vickers, 2007) - is proposed to benefit performance by extending a critical period of information processing during which the motor response is selected, fine-tuned, and programmed (Mann, Coombes, Mousseau, & Janelle, 2011). Given the aforementioned research, a challenge state might therefore result in better performance than a threat state by encouraging more effective utilisation of attention (i.e., less conscious processing and/or longer quiet eye durations).

1.3.3 Behavioural Mechanisms

Blascovich and other authors have argued that a challenge state is associated with approach motivation and a threat state is related to avoidance motivation (Blascovich, 2014; Jones et al., 2009). Approach motivation is defined as the energisation of behaviour directed toward positive or desirable situations and stimuli. In contrast, avoidance motivation is defined as the energisation of behaviour directed away from negative or undesirable situations and stimuli (Elliot & Trash, 2002). Thus, challenge and threat states are predicted to lead to different behaviours and movements. Indeed, a small number of studies have supported this proposition (O'Connor et al., 2010; Weisbuch, Seery, Ambady, & Blascovich, 2009). For example, Mendes and colleagues found that, compared to a challenge state, a threat state resulted in

less effective movements during a social interaction task, including greater freezing, avoidance posture, and less smiling (Mendes, Blascovich, Hunter, Lickel, & Jost, 2007). Thus, a challenge state might result in superior performance than a threat state by encouraging task-related behaviours and movement patterns that are more likely to translate to successful performance.

In addition, authors have suggested that muscular tension may be greater during a threat state than a challenge state (Wright & Kirby, 2003). For instance, Blascovich and Mendes (2000) suggested that challenge and threat states might result in differences in facial electromyographic activity, with a challenge state associated with higher zygomaticus major (cheek) activity and a threat state related to greater corrugator supercilii (brow) activity. However, despite these suggestions, to date, no studies have been conducted to examine this proposition. Research has shown that lower muscle activity is typically associated with more successful performance. For example, Lay and colleagues found that as participants learnt and became more proficient at a rowing task, muscle activation decreased (Lay, Sparrow, Hughes, & O'Dwyer, 2002). Furthermore, research has demonstrated that elevated muscular activity can have negative effects on task performance under pressure (Weinberg & Hunt, 1976). Thus, a challenge state might lead to better performance than a threat state by encouraging lower activation of task-relevant muscles.

1.4 Predicted Antecedents

According to the BPSM, the demand/resource evaluation process is complex and thus challenge and threat states can be influenced by many interrelated factors (Blascovich, 2014). Early conceptions of the BPSM attempted to identify factors that could influence evaluated demands (i.e.,

danger, uncertainty, and required effort) and resources (i.e., skills, knowledge, and abilities) separately (Blascovich & Mendes, 2000; Blascovich & Tomaka, 1996). However, recent revisions of the BPSM have emphasised that antecedents including psychological and physical danger, familiarity, uncertainty, required effort, skills, knowledge and abilities, and the availability of support could impact upon both demand and resource evaluations (Blascovich, 2008a; Frings, Rycroft, Allen, & Fenn, 2014). For example, a motivated performance situation that is perceived as requiring little effort to perform effectively, could contribute to lower demand and higher resource evaluations (and thus a challenge state). In contrast, a situation that is perceived as requiring greater effort to perform, could lead to higher demand and lower resource evaluations (and thus a threat state). Furthermore, recent revisions of the BPSM acknowledge that these antecedents are not independent of each other and can overlap and interact (Blascovich, 2008a). For example, a situation that is unfamiliar to an individual could be viewed as more dangerous and with greater uncertainty than a situation that is familiar.

As mentioned above, the cardiovascular markers of challenge and threat states have been used to test various psychological theories (see section 1.2.3). While some of these theories have focused on inter-individual processes (e.g., social comparison; Mendes et al., 2001), others have concerned intra-individual processes and have therefore inadvertently offered antecedents that influence demand/resource evaluations and challenge and threat states (Seery et al., 2004; Tomaka & Blascovich, 1994; Weisbuch-Remington et al., 2005). For example, Scheepers and colleagues examined the influence of social power on individuals' cardiovascular responses to a negotiation task. The authors found that individuals who perceived that they had high social power exhibited a

challenge state and performed better in the negotiation task than individuals who perceived that they had low social power who displayed a threat state and poorer negotiation performance (Scheepers et al., 2012). While this research has given an indication of some antecedents, no previous research has explicitly examined any of the antecedents outlined by the BPSM and if they interact and influence demand/resource evaluations and challenge and threat states. Furthermore, no research has examined if any of the predicted antecedents impact the performance of cognitive or motor tasks.

Two of these predicted antecedents, required effort and support availability, may offer a good departure point for such research, as these antecedents have received particular attention in recent reviews (McGrath, Moore, Wilson, Freeman, & Vine, 2011; Seery, 2013). Indeed, substantial research has examined the influence of effort intensity on cardiovascular responses during cognitive tasks (Gendolla & Wright, 2012; Wright & Kirby, 2001). For example, Richter and colleagues measured participants' cardiovascular responses during a resting baseline and during the completion of a memory recognition task of varying difficulties. The authors found that as the difficulty increased and participants had to expend more effort to complete the task, systolic blood pressure and pre-ejection period reactivity increased (Richter, Friedrich, & Gendolla, 2008). Despite this research, no studies have examined if perceptions relating to the effort required to complete an upcoming task influence the cardiovascular markers of challenge and threat states (i.e., cardiac output and total peripheral resistance). However, as perceptions of required effort have been proposed to influence demand/resource evaluations, with less required effort resulting in lower demand evaluations and higher

resource evaluations, low required effort could lead to a challenge state (Blascovich & Mendes, 2000; Seery, 2013).

Furthermore, considerable research has investigated the influence of social support on cardiovascular responses to stressful tasks (Uchino, Cacioppo & Kiecolt-Glaser, 1996). While much of this research has focused on received support, which refers to the specific helping actions provided to an individual by others during a specific time frame, this research has also examined perceived support, which reflects an individual's subjective assessment that assistance would be provided by others if required (Freeman & Rees, 2010). For example, Uchino and Garvey (1997) focused on perceptions of support availability and asked participants to complete a speech task under either no support or support available conditions while cardiovascular responses were recorded. The authors found that participants in the support available condition displayed lower systolic and diastolic blood pressure reactivity than participants in the no support condition. Although research has investigated the effects of perceived support on blood pressure, limited research has examined the influence perceived support can have on the cardiovascular indices of challenge and threat states. However, as perceptions of support availability have been proposed to impact demand/resource evaluations, with support availability leading to lower demand evaluations and higher resource evaluations, available support might result in a challenge state (McGrath et al., 2011).

1.5 Summary and Aims of Thesis

This thesis adopts the BPSM (Blascovich, 2008a) as a theoretical framework to aid our understanding of performance variability under pressure. Specifically, this thesis will aid the identification of individuals who are likely to

perform well in pressurised situations and those who may benefit from an intervention aimed at improving their performance. According to the BPSM, prior to a potentially stressful motivated performance situation, individuals evaluate the demands of the situation and their personal coping resources. Individuals who believe that they possess the resources required to cope with the demands of the situation, evaluate the situation as a challenge. In contrast, individuals who judge that they do not possess the required resources, evaluate the situation as a threat (Blascovich, 2008a). The BPSM predicts that these demand/resource evaluations lead to distinct cardiovascular responses. Specifically, individuals who evaluate the situation as a challenge exhibit a cardiovascular response consisting of relatively higher cardiac output and lower total peripheral resistance compared to individuals who evaluate the situation as a threat (Seery, 2011). According to the BPSM, these divergent demand/resource evaluations and cardiovascular responses are proposed to result in different performance outcomes; with a challenge state leading to better task performance than a threat state (Blascovich, 2008a).

A number of correlational studies have demonstrated that a challenge state predicts superior future task performance than a threat state in a laboratory setting (e.g., Turner et al., 2012; Turner et al., 2013). However, to date, no research has experimentally manipulated challenge and threat states and examined their *immediate* effects on laboratory-based motor performance. Furthermore, various studies have shown that a challenge state predicts better future real-world performance relative to a threat state (e.g., Blascovich et al., 2004; Seery et al., 2010). However, to date, no research has examined whether challenge and threat states, assessed *immediately* before a real pressurised competition, are associated with varying levels of performance. Such research

is important as the stronger research designs and shorter time periods between the assessment of challenge and threat states and performance will give a more causal understanding of the relationship between these states and performance. Subsequently, this thesis aims to shed light on these issues and to investigate the immediate effects of challenge and threat states on the performance of individuals (novice and experienced) in both laboratory-based motor tasks and real pressurised competition.

Several underlying mechanisms have been proposed to explain how challenge and threat states influence performance including those related to emotions, attention, and behaviour (Blascovich et al., 2004; Jones et al., 2009). However, limited research has examined these possible mechanisms. Thus, this thesis will extend research in this area and assess the mechanisms through which challenge and threat states impact motor performance. The findings will aid the development of the BPSM as well as other theories who have adopted its central tenets (e.g., TCTSA; Jones et al., 2009). Moreover, according to the BPSM, a range of interrelated factors are predicted to influence both demand and resource evaluations including psychological and physical danger, familiarity, uncertainty, required effort, skills, knowledge and abilities, and the availability of support (Blascovich, 2008a). However, to date, no research has explicitly examined the effect of any of these antecedents on demand/resource evaluations, challenge and threat states, and motor performance. This thesis will therefore begin work in this area and examine the impact of two of these antecedents: perceived required effort and support availability. The findings will benefit the design of interventions aimed at promoting a challenge state and preventing a threat state in response to pressurised situations.

Given the aforementioned research and summary, the aims of this thesis are:

1) To examine the immediate effect of challenge and threat states on the performance of novice participants in a golf putting task and to identify the potential mechanisms through which these states operate.

2) To investigate the immediate effect of challenge and threat states on the performance of experienced golfers during a real pressurised golf competition. Also, to examine the immediate impact of challenge and threat states on the golf putting performance of experienced golfers and to identify the possible mechanisms through which these states influence performance.

3) To examine the impact of perceived required effort and support availability on demand/resource evaluations, challenge and threat states, and motor performance.

The first aim of this thesis is addressed empirically in the next chapter.

CHAPTER 2: THE EFFECT OF CHALLENGE AND THREAT STATES ON PERFORMANCE: AN EXAMINATION OF POTENTIAL MECHANISMS

2.1 Introduction

Like many other contexts (e.g., surgery, military, aviation), competitive sport is characterised by highly pressurised situations that place individuals under extreme stress. However, research examining the effects of stress on sporting task performance has shown considerable variability; from no effect, to either facilitative or debilitative effects (see Hanton et al., 2008 for a review). This variability is likely caused by the individualistic way in which individuals respond to stress (Cerin, Szabo, Hunt, & Williams, 2000). One theoretical framework that offers a potential explanation for such individual differences in stress response is the biopsychosocial model (BPSM) of challenge and threat (Blascovich, 2008a).

According to the BPSM (Blascovich, 2008a), prior to a task, individuals evaluate the demands of the task (demand evaluation) and whether they possess the necessary resources to cope effectively with these demands (resource evaluation). Importantly, these evaluations only occur in motivated performance situations (e.g., exam taking, speech giving, sporting competition) and when individuals are actively engaged in a task; evidenced by increases in heart rate and reductions in cardiac pre-ejection period (Seery, 2011). When an individual evaluates that he or she has sufficient resources to meet the demands of the task, a challenge state occurs. In contrast, when an individual evaluates that he or she does not possess the resources required to meet the demands of the task, a threat state emerges (Seery, 2011). Demand and resource evaluations are not only influenced by whether the individual

possesses the skills, knowledge, and abilities to perform well on the task. Indeed, several other factors are proposed to impact both demand and resource evaluations including psychological and physical danger, familiarity, uncertainty, required effort, and the presence of others (Blascovich, 2008a).

Demand and resource evaluations can occur consciously, unconsciously (i.e., automatically), or both (Blascovich, 2008a). However, most authors argue these evaluations are predominately unconscious and automatic, with an individual arriving at a challenge or threat state without any awareness of the evaluation process (Blascovich & Mendes, 2000; Seery, 2011). Thus, a critical component of the BPSM is that challenge and threat states are best indexed objectively via distinctive patterns of neuroendocrine and cardiovascular responses (Blascovich, 2008a; Seery, 2011). Both challenge and threat states are hypothesised to result in elevated sympathetic-adrenomedullary activation causing the release of catecholamines, whilst a threat state is also predicted to result in elevated pituitary-adrenocortical activation causing the release of cortisol (Seery, 2011). Consequently, a challenge state is marked by relatively higher cardiac output and lower total peripheral resistance compared to a threat state (Seery, 2011). These cardiovascular markers have been well validated in the literature (see Blascovich, 2008a, for a review).

Empirical and predictive studies in psychology, across a range of tasks and contexts, have shown that a challenge state facilitates performance whilst a threat state hinders performance (Gildea et al., 2007; Mendes, Blascovich, Hunter, Lickel, & Jost, 2007; Seery et al., 2010). For example, Blascovich and colleagues found that baseball and softball players who displayed cardiovascular markers of challenge during a three minute sport-relevant

speech, four to six months prior to the start of the season, performed better during the subsequent season than players who displayed markers of threat (Blascovich et al., 2004). To date, no research has examined the immediate effects of challenge and threat states on motor task performance, with most studies only investigating distant effects on real-world performance (e.g., academic; Seery et al., 2010) or immediate effects on cognitive task performance (e.g., word-finding; Mendes et al., 2007).

Furthermore, limited research has examined the potential mechanisms through which challenge and threat states influence performance (O'Connor et al., 2010). This is surprising given the potential for such research to enhance theory and guide the development of theory-led interventions. Several underlying mechanisms have been proposed including those related to emotions, attention, and physical functioning (Blascovich et al., 2004; Jones et al., 2009; Skinner & Brewer, 2004).

A challenge state is said to be associated with both positive and negative emotions, while a threat state is associated with only negative emotions (Jones et al., 2009; Skinner & Brewer, 2004). Furthermore, emotions are proposed to be interpreted as facilitative for performance in a challenge state but debilitative in a threat state (Jones et al., 2009; Skinner & Brewer, 2004). Recent research has supported this, demonstrating that a threat state is associated with greater cognitive and somatic anxiety, and a more debilitative interpretation of anxiety responses compared to a challenge state (Quested et al., 2011; Williams et al., 2010). Positive and negative emotions are typically associated with successful and unsuccessful performance, respectively, whilst facilitative interpretations of emotions predict more successful performance relative to debilitative

interpretations (e.g., Nicholls et al., 2012; Thomas et al., 2007). A challenge state might therefore result in superior performance by promoting more favourable emotional responses (i.e., lower negative and higher positive emotions) and interpretation of emotions (i.e., more facilitative for performance).

A challenge state may also be associated with more effective attention compared to a threat state (Blascovich et al., 2004; Jones et al., 2009; Skinner & Brewer, 2004). During a challenge state the focus of attention is proposed to be on task-relevant cues, whereas in a threat state, attention is also directed to task-irrelevant cues (Jones et al., 2009). Research employing eye-tracking technology to objectively measure attention has demonstrated that efficient attention in aiming tasks is characterised by longer quiet eye durations (see Mann et al., 2007 for a review). The quiet eye is defined as the final fixation towards a relevant target prior to the initiation of a movement (Vickers, 2007). Longer quiet eye durations are proposed to extend a critical period of time during which task-relevant information gathered by preparatory fixations is processed and used to select, fine-tune and program the motor response, resulting in more accurate performance (Mann et al., 2011). Thus, a challenge state might result in better performance by encouraging more effective attentional control (i.e., longer quiet eye durations).

A small number of studies have shown that challenge and threat states lead to divergent behaviours or movements (O'Connor et al., 2010; Weisbuch et al., 2009). For example, Mendes and colleagues found that, compared to a challenge state, a threat state resulted in less effective movements during an interaction task; including greater freezing, avoidance posture and less smiling (Mendes et al., 2007). Thus, a challenge state might result in superior

performance by encouraging task-related movement patterns that are more likely to translate to successful performance. Additionally, authors have suggested that muscular tension is likely to be greater during a threat state than a challenge state (Wright & Kirby, 2003). To date, no studies have examined this proposition. However, given that lower muscle activity is typically associated with more successful performance (Lay et al., 2002) a challenge state might lead to better performance by encouraging lower activation of task-relevant muscles.

The aim of the present study was to examine the influence of challenge and threat states on the performance of novice participants in a golf putting task and to identify the potential mechanisms through which these states operate (emotional, attentional, kinematic, and/or physiological). It was predicted that the challenge group would display relatively higher cardiac output and lower total peripheral resistance compared to the threat group. Additionally, it was predicted that the challenge group would perform better in the golf putting task than the threat group; display a more favourable emotional response (i.e., intensity and direction of cognitive and somatic anxiety); and display more effective attentional control (i.e., longer quiet eye durations), putting kinematics (i.e., lower clubhead acceleration and jerk), and muscle activity (i.e., lower extensor carpi radialis activity). Finally, to explore if differences in any of the process measures mediated any between-group differences in performance, mediation analyses were conducted (Hayes & Preacher, 2013).

2.2 Method

2.2.1 Participants

One hundred and twenty-seven undergraduate students (63 women, 64 men) with a mean age of 19.47 years (SD = 2.48) participated in the study. All participants declared having no official golf handicap or prior formal golf putting experience and thus, were considered novice golfers (Cooke, Kavussanu, McIntyre, & Ring, 2010; Moore, Vine, Cooke, Ring, & Wilson, 2012). Furthermore, all reported being right-handed, non-smokers, free of illness or infection, and had normal or corrected vision, no known family history of cardiovascular or respiratory disease, had not performed vigorous exercise or ingested alcohol for 24 hours prior to testing, and had not consumed food and/or caffeine for 1 hour prior to testing. Participants were tested individually. The protocol was approved by the local ethics committee and written informed consent was obtained from each participant.

2.2.2 Measures

2.2.2.1 Demand/Resource Evaluations. Demand and resource evaluations were assessed using the cognitive appraisal ratio (Tomaka et al., 1993). Demand evaluations were assessed by asking "How demanding do you expect the golf putting task to be?", whilst resource evaluations were assessed by asking "How able are you to cope with the demands of the golf putting task?". These two items were rated using a 6-point Likert scale anchored between *not at all (= 1)* and *extremely (= 6).* A ratio was then calculated by dividing demands by resources such that a value greater than 1 indicated a threat state, while a value less than 1 indicated a challenge state. This self-report measure has been widely used in the challenge and threat literature (e.g., Feinberg & Aiello, 2010).

2.2.2.2 Cognitive and Somatic State Anxiety. The immediate anxiety measurement scale (IAMS; Thomas, Hanton, & Jones, 2002) was employed to assess the intensity and directional interpretation of anxiety symptoms experienced by participants. The IAMS provides definitions of cognitive and somatic anxiety, after which participants completed four items measuring the intensity and direction of each construct. The items were rated using a 7-point Likert scale anchored between *not at all (= 1)* and *extremely (= 7)* for intensity and *very negative (= -3)* and *very positive (= +3)* for direction. Thomas and colleagues (2002) provided evidence for the validity and reliability of this measure and it has been used previously in the challenge and threat literature (e.g., Williams et al., 2010).

2.2.2.3 Performance (Mean Radial Error). Mean radial error (the average distance the ball finished from the hole in cm) was recorded as a measure of task performance. Zero was recorded and employed in the calculation of mean radial error on trials where the putt was holed (Cooke et al., 2010; Moore et al., 2012). Furthermore, on trials where the ball hit the boundary of the putting green (90 cm behind the hole) the largest error possible was recorded (90 cm). This occurred on 105 (14 %) of the 762 trials (challenge = 32, threat = 73).

2.2.2.4 Quiet Eye Duration. Gaze was measured using an Applied Science Laboratories (ASL; Bedford, MA, USA) Mobile Eye Tracker. This lightweight system utilises two features; the pupil and corneal reflection (determined by the reflection of an infrared light source from the surface of the cornea) to calculate point of gaze (at 30 Hz) relative to eye and scene cameras mounted on a pair of spectacles. A circular cursor, representing 1° of visual

angle with a 4.5 mm lens, indicating the location of gaze in a video image of the scene (spatial accuracy of ± 0.5° visual angle; 0.1° precision), was viewed by the research assistant in real time on a laptop screen (Lenovo R500 ThinkPad) installed with *Eyevision* (ASL) recording software. Participants were connected to the laptop via a 10 m fire wire cable and the researcher and laptop were located behind the participant to minimise distractions. The video data was recorded for subsequent offline analysis.

The quiet eye duration was operationally defined as the final fixation towards the ball prior to the initiation of the backswing (Vickers, 2007). Quiet eye onset occurred before the backswing and quiet eye offset occurred when the gaze deviated off the fixated object by 1° or more, for greater than 100 ms. A fixation was defined as a gaze maintained on an object within 1° of visual angle for a minimum of 100 ms (Moore et al., 2012). Each putt was subject to frame-by-frame video analysis using Quiet Eye Solutions software (www.QuietEyeSolutions.com). Unfortunately, gaze data for 21 participants (challenge = 10, threat = 11) could not be analysed due to poor calibration. Thus, a total of 636 putts were analysed. The researcher was blind to the test and status (group) of each participant when analysing the data. A second analyst blindly scored 10% of the quiet eye duration data and inter-rater reliability was assessed using the interobserver agreement method (Thomas & Nelson, 2001). This method estimates reliability using a formula that divides the number of commonly coded quiet eye durations (i.e., within 33.33 ms) by the sum of the commonly coded quiet eye durations and quiet eye durations coded differently. This analysis revealed a level of agreement at 81%.

2.2.2.5 Cardiovascular Measures. A non-invasive impedance cardiograph device (Physioflow, PF05L1, Manatec Biomedical, Paris, France) was used to estimate heart rate and cardiac output. The theoretical basis for this device and its validity during rest and exercise testing has been published previously (e.g., Charloux et al., 2000). The Physioflow measures impedance changes in response to a high frequency (75 kHz) and low-amperage (3.8 mA) electrical current emitted via electrodes. Following preparation of the skin, six spot electrodes (Blue Sensor R, Ambu, Ballerup, Denmark) were positioned on the thorax; two on the supraclavicular fossa of the left lateral aspect of the neck, two near the xiphisternum at the midpoint of the thoracic region of the spine, one on the middle of the sternum, and one on the rib closest to V6. After entering the participant's details (i.e., height, weight etc.), the Physioflow was calibrated over 30 heart cycles while participants sat resting in an upright position. Three resting systolic and diastolic blood pressure values were taken (one prior to the 30 heart cycles, one during this time period, and another immediately after this time period) manually by a trained experimenter using an aneroid sphygmomanometer (ACCOSON, London, UK) and stethoscope (Master Classic II, Littmann, 3M Health Care, St. Paul, USA). The mean blood pressure values were entered into the Physioflow to complete the calibration procedure. Heart rate, stroke volume, and cardiac output were estimated continuously during baseline (5 minutes) and post-manipulation (1 minute) time periods. Participants remained seated throughout these time periods. Reactivity, or the difference between the final minute of baseline and the minute post-manipulation, was examined for all cardiovascular variables.

Both heart rate and cardiac pre-ejection period are considered cardiovascular markers of task engagement; with greater increases in heart rate

and greater decreases in cardiac pre-ejection period reflecting greater task engagement (Seery, 2011). The Physioflow does not allow for the computation of cardiac pre-ejection period and so only heart rate was used in the present study to assess task engagement (as Derks, Scheepers, Van Laar, & Ellemers, 2011). Cardiac output and total peripheral resistance are cardiovascular indices that differentiate challenge and threat; with higher cardiac output and lower total peripheral resistance more reflective of a challenge state (Seery, 2011). Cardiac output was estimated directly by the Physioflow whilst total peripheral resistance was calculated using the formula: [mean arterial pressure x 80 / cardiac output] (Sherwood, Allen, Fahrenberg, Kelsey, Lovallo, & Van Dooren, 1990). Mean arterial pressure was calculated using the formula: [(2 x diastolic blood pressure) + systolic blood pressure / 3] (Cywinski, 1980).

2.2.2.6 Putting Kinematics. Acceleration of the clubhead in three axes was recorded using a tri-axial accelerometer (LIS3L06AL, ST Microelectronics, Geneva, Switzerland). Acceleration on the X, Y, and Z axes corresponded to lateral, vertical, and back-and-forth movement of the clubhead, and assessed clubhead orientation, clubhead height, and impact velocity, respectively. The signals were conditioned by a bespoke buffer amplifier with a frequency response of DC to 15 Hz. Both accelerometer and amplifier were mounted in a 39 mm x 20 mm x 15 mm plastic housing secured to the rear of the clubhead. A microphone (B5 Condenser, Behringer, Germany) connected to a mixing desk (Eurorack UB802, Behringer, Germany) was used to detect the putter-ball contact on each trial. These signals were digitized at 2500 Hz. A computer program determined clubhead kinematics for each putt from the onset of the foreswing phase of the putting stroke until the point of putter-ball contact. The average acceleration was calculated for the X, Y, and Z axes. Peak acceleration

and root mean square jerk were also calculated for the Z-axis as the primary axis involved in golf putting. The values from all trials were averaged to provide a test mean value for each kinematic variable (Cooke et al., 2010; Moore et al., 2012).

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

2.2.3 Procedure

Firstly, participants were fitted with the physiological recording equipment and ASL Mobile eye-tracker. Subsequently, 5 minutes of baseline

cardiovascular data was recorded whilst participants sat still and quietly. Next, participants received their respective manipulation (challenge or threat; see section 2.2.4). This was followed by a 1 minute period during which cardiovascular data was recorded. Participants then completed the cognitive appraisal ratio and IAMS before performing six straight putts from three, 1.83 m locations to a half-size hole (diameter = 6 cm) on an artificial putting green (length = 6 m, width = 2.5 m; Stimpmeter reading = 3.28 m). All participants used a standard length (90 cm) steel-shafted blade style golf putter (Sedona 2, Ping, Phoenix, AZ) and regular-size (diameter = 4.27 cm) white golf balls. Performance, gaze behaviour, muscle activity and kinematic data were continuously recorded throughout all putts. Finally, once the physiological recording equipment and ASL Mobile eye-tracker had been removed, participants were thanked and debriefed about the aims of the study.

2.2.4 Challenge and Threat Manipulations

Participants were randomly assigned to the two experimental groups. Challenge and threat states were manipulated through the instructional set given to participants. The instructions were adapted from previous research (e.g., Feinberg & Aiello, 2010; O'Connor et al., 2010). To foster task engagement, both groups received instructions emphasising the importance of the task; that their score would be compared against others taking part (published leader board); that the task was going to be objectively evaluated (digital video camera); that low performing participants would be interviewed; and that financial rewards existed for high performing participants (top 5 performers awarded cash prizes of £50, £25, £20, £15, and £10, respectively). The threat instructions focused on the task's high degree of difficulty and

emphasised that previous participants had struggled to perform well on the task. The challenge instructions focused on participants perceiving the task as a challenge to be met and overcome, thinking of themselves as capable of meeting that challenge, and emphasised that previous participants had performed well on the task (see Appendix 2).

2.2.5 Statistical Analysis

To ensure any between-group differences were not due to differences in gender, a series of independent *t*-tests were conducted. These analyses revealed gender differences for cognitive appraisal ratio, cognitive anxiety direction, quiet eye duration, and muscle activity during the backswing, foreswing, and post-contact. Subsequently, one-way analyses of covariance (ANCOVA) were conducted to examine between-group differences for these variables. The independent *t*-tests revealed no gender differences for cognitive anxiety intensity, somatic anxiety intensity and direction, mean radial error, muscle activity pre-initiation, and all putting kinematic variables (X, Y, and Z-axis acceleration, peak acceleration, and root mean square jerk). Thus, a series of independent *t*-tests were conducted on these variables to examine differences between the groups. Effect sizes were calculated using partial eta squared (ANCOVA) or Cohen's *d* (*t*-test).

No gender differences existed for the cardiovascular variables. Task engagement was assessed using a dependent *t*-test on the heart rate reactivity data to establish that in the sample as a whole, heart rate increased significantly from baseline (i.e., heart rate reactivity greater than zero; as Seery, Weisbuch, & Blascovich, 2009). Four univariate outliers (values more than 3.3 standard deviation units from the grand mean; Tabachnick & Fidell, 1996) from two

participants were winsorised by changing the deviant raw score to a value 1 % larger or smaller than the next most extreme score (as Shimizu et al., 2011). In order to differentiate challenge and threat states an index was created by converting each participant's cardiac output and total peripheral resistance residualised change scores into z-scores and summing them. Residualised change scores were calculated in order to control for baseline values. Total peripheral resistance was assigned a weight of -1 and cardiac output a weight of +1, such that a larger value corresponded with greater challenge (as Seery et al., 2009). To compare the groups, an independent *t*-test was conducted on the challenge and threat index data.

Finally, to determine if significant differences in any of the process measures mediated any between-group differences in performance, mediation analyses were performed using the MEDIATE SPSS custom dialog developed by Hayes and Preacher (Hayes & Preacher, 2013). This custom dialog tests the total, direct and indirect effect of an independent variable on a dependent variable through a proposed mediator and allows inferences regarding indirect effects using percentile bootstrap confidence intervals.

2.3 Results

2.3.1 Manipulation Checks

The dependent *t*-test on the heart rate reactivity data revealed that in the sample as a whole, heart rate significantly increased from baseline, $t(121) = 15.11$, $p < .001$, $d = 2.75$, enabling the examination of challenge and threat states. The independent *t*-test on the challenge and threat index data revealed a significant difference between the groups, $t(120) = 2.63$, $p = .01$, $d = 0.48$, with the challenge group ($M = 0.45$, $SD = 2.05$) exhibiting a larger index value

than the threat group (M = -0.46, SD = 1.72). Furthermore, the one-way ANCOVA on the demand/resource evaluation data also revealed a significant difference between the groups, $F(1, 124) = 45.89$, $p < .001$, $\eta_p^2 = .27$, with the challenge group reporting a lower ratio score (M = 0.79, SD = 0.39) than the threat group (M = 1.39, SD = 0.62).

2.3.2 Performance (Mean Radial Error)

The independent t-test on the mean radial error data revealed a significant difference between the groups, $t(125) = 3.84$, $p < .001$, $d = 0.69$, with the challenge group (M = 35.48, SD = 14.82) achieving a lower mean radial error than the threat group (M = 46.53, SD = 17.45).

2.3.3 Cognitive and Somatic Anxiety

The ANCOVA and independent t-tests on the IAMS data revealed no significant difference between the groups in terms of the intensity of somatic anxiety, $t(125) = 1.59$, $p = .12$, $d = 0.28$, but significant differences between the groups in terms of the intensity of cognitive anxiety, $t(125) = 2.86$, $p = .005$, $d = 0.51$. The challenge group reported experiencing lower levels of cognitive anxiety than the threat group. Furthermore, these analyses revealed significant differences between the groups in terms of the direction of cognitive anxiety, $F(1, 124) = 18.38$, $p < .001$, $\eta_p^2 = .13$, and somatic anxiety, $t(125) = 2.45$, $p = .016$, $d = 0.44$. Compared to the threat group, the challenge group interpreted the cognitive anxiety they experienced as more facilitative for their performance and the somatic anxiety they experienced as less debilitative. The cognitive and somatic anxiety data are presented in Table 2.1.

2.3.4 Quiet Eye Duration

The ANCOVA on the quiet eye duration data revealed a significant difference between the groups in terms of quiet eye duration, $F(1, 101) = 5.06$, $p = .027$, $\eta_p^2 = .05$. The challenge group displayed longer quiet eye durations than the threat group. The gaze data are presented in Table 2.1.

2.3.5 Putting Kinematics

The independent t-tests on the putting kinematic data revealed significant differences between the groups in terms of X-axis acceleration, $t(124) = 2.68$, $p = .008$, $d = 0.48$; Y-axis acceleration, $t(124) = 2.38$, $p = .018$, $d = 0.43$; Z-axis acceleration, $t(124) = 3.08$, $p = .003$, $d = 0.55$; peak acceleration, $t(124) = 3.30$, $p < .001$, $d = 0.59$; and root mean square jerk, $t(124) = 3.02$, $p = .003$, $d = 0.54$. The challenge group displayed lower lateral, vertical, back-and-forth acceleration as well as lower peak acceleration and less root mean square jerk compared to the threat group. The putting kinematic data are presented in Table 2.1.

2.3.6 Muscle Activity

The ANCOVA and independent t-tests on the muscle activity data revealed no significant difference between the groups during pre-initiation, $t(124) = 1.33$, $p = .19$, $d = 0.24$; or the backswing, $F(1, 123) = 0.86$, $p = .36$, $\eta_p^2 = .01$; but a significant difference between the groups during the foreswing, $F(1, 123) = 3.72$, $p = .054$, $\eta_p^2 = .03$; and post-contact, $F(1, 123) = 5.40$, $p = .022$, $\eta_p^2 = .04$. The challenge group exhibited less muscle activity during the foreswing phase and after putter-ball contact compared to the threat group. The muscle activity data are presented in Table 2.1.

Table 2.1 Mean (*SD*) emotional, gaze, putting kinematic, and muscle activity data for challenge and threat groups.

	Challenge		Threat	
	Mean	*SD*	Mean	*SD*
Cognitive anxiety intensity	3.05**	1.10	3.63	1.18
Cognitive anxiety direction	0.02***	1.14	-0.83	0.98
Somatic anxiety intensity	2.92	1.21	3.27	1.25
Somatic anxiety direction	-0.10*	1.07	-0.53	0.93
Quiet eye duration (ms)	1527.34*	814.28	1194.86	582.49
X-axis acceleration (m.s⁻²)	0.55**	0.25	0.69	0.33
Y-axis acceleration (m.s⁻²)	0.72*	0.20	0.83	0.31
Z-axis acceleration (m.s⁻²)	3.67**	1.12	4.33	1.26
Peak acceleration (m.s⁻²)	4.62***	1.31	5.48	1.58
Root mean square jerk (m.s⁻²)	3.71**	1.10	4.36	1.29
Pre-initiation muscle activity (µV)	15.12	7.39	17.98	15.36
Backswing muscle activity (µV)	22.36	13.92	25.60	18.56
Foreswing muscle activity (µV)	26.90*	17.93	34.63	22.50
Post-contact muscle activity (µV)	21.41*	11.07	28.61	19.72

Note: significantly different from threat group, $* = p < .05$, $** = p < .01$, $*** = p < .001$.

2.3.7 Mediation Analyses

To test if the effect of group on performance was mediated by any of the process variables, experimental group (coded: challenge = 1, threat = 0) was entered as the independent variable, mean radial error was entered as the dependent variable, and a number of potential mediators were entered separately. Based on a 10,000 sampling rate, the results from bootstrapping revealed no significant indirect effects for cognitive anxiety intensity, 95% CI = -1.88 to 1.54; cognitive anxiety direction, 95% CI = -1.17 to 3.65; somatic anxiety intensity, 95% CI = -0.81 to 1.24; quiet eye duration, 95% CI = -2.09 to 1.53; pre-initiation muscle activity, 95% CI = -1.49 to 0.87; backswing muscle activity, 95% CI = -1.60 to 0.62; foreswing muscle activity, 95% CI = -3.11 to 0.21; or post-contact muscle activity, 95% CI = -2.84 to 0.48.

There were significant indirect effects for somatic anxiety direction, 95% CI = 0.01 to 3.45; X-axis acceleration, 95% CI = -6.39 to -0.88; Y-axis acceleration, 95% CI = -6.14 to -0.62; Z-axis acceleration, 95% CI = -5.20 to -0.71; peak acceleration, 95% CI = -5.97 to -0.83; and root mean square jerk, 95% CI = -5.15 to -0.70. Thus, multiple kinematic variables mediated the relationship between group and mean radial error. However, for somatic anxiety direction, the indirect (b = 1.42) and direct (b = -12.47) effects had opposite signs and the direct effect was greater than the total (b = -11.05) effect. Thus, somatic anxiety direction had a suppression effect on the relationship between group and mean radial error (MacKinnon, Krull, & Lockwood, 2000). The mediation results are presented in Table 2.2.

Table 2.2 Mediation results for all emotional, gaze, putting kinematic, and muscle activity variables.

	Effect	*SE*	LL 95% CI	UL 95% CI
Cognitive anxiety intensity	-0.17	0.82	-1.88	1.54
Cognitive anxiety direction	1.03	1.22	-1.17	3.65
Somatic anxiety intensity	0.15	0.48	-0.81	1.24
Somatic anxiety direction	1.42	0.89	0.01	3.45*
Quiet eye duration	-0.53	1.07	-2.90	1.53
X-axis acceleration	-3.50	1.41	-6.39	-0.88*
Y-axis acceleration	-3.28	1.43	-6.14	-0.62*
Z-axis acceleration	-2.62	1.15	-5.20	-0.71*
Peak acceleration	-3.00	1.31	-5.97	-0.83*
Root mean square jerk	-2.63	1.14	-5.15	-0.70*
Pre-initiation muscle activity	-0.28	0.57	-1.49	0.87
Backswing muscle activity	-0.25	0.54	-1.60	0.62
Foreswing muscle activity	-1.07	0.87	-3.11	0.21
Post-contact muscle activity	-1.13	0.85	-2.84	0.48

Note: LL = lower limit; CI = confidence interval; UL = upper limit, * = significant indirect effect

2.4 Discussion

A challenge state has been associated with superior distant real-world performance compared to a threat state (Blascovich et al., 2004); however, no research has examined the immediate effect of these states on motor task

performance. Furthermore, no research has examined the potential mechanisms through which these states might influence performance. Thus, the purpose of the present study was to investigate the immediate effect of challenge and threat states on the performance of novice participants in a golf putting task and examine multiple possible underlying processes.

Consistent with previous research, challenge and threat states were manipulated via task instructions (e.g., Feinberg & Aiello, 2010; Tomaka et al., 1997). The demand/resource evaluation data supported the effectiveness of the manipulation, as the challenge group reported a mean ratio score less than one, reflecting a challenge state, and the threat group reported a mean ratio score greater than one, reflecting a threat state. Thus, whilst the challenge group evaluated that they possessed the resources required to cope with the demands of the task, the threat group evaluated that they had insufficient resources to cope with the task demands. Several authors have criticised self-report measures of challenge and threat states (e.g., Blascovich et al., 2004), therefore, the present study also adopted objective cardiovascular measures. Importantly, the heart rate data revealed that the whole sample were actively engaged in the task, as evidenced by increases in heart rate, allowing further examination of challenge and threat cardiovascular responses (Seery, 2011). The challenge and threat index data further supported the effectiveness of the manipulation, as the challenge group exhibited a larger index value, reflecting greater challenge (relatively higher cardiac output and lower total peripheral resistance; Seery, 2011), compared to the threat group.

As hypothesised, the performance data revealed that the challenge group performed better in the golf putting task than the threat group, achieving a

lower mean radial error. This result equated to a medium to large effect size and is congruent with previous research showing that a challenge state is associated with higher levels of performance compared to a threat state (Gildea et al., 2007; Mendes et al., 2007; Seery et al., 2010). For example, Blascovich and colleagues demonstrated that experiencing a challenge state in response to a sport-relevant speech task was associated with superior real-world performance during the following season (Blascovich et al., 2004). The present study extends this research and is the first to demonstrate the immediate and direct effect (i.e., ~ 2 minutes post-manipulation) of challenge and threat states on the performance of a novel motor task, with a challenge state resulting in superior motor task performance relative to a threat state. Given this finding it is important to establish the underlying mechanisms through which these states influence performance as such information may enhance theory and aid the design of effective theory-led interventions.

The IAMS data revealed, as hypothesised, that challenge and threat states were associated with different emotional responses. There were no differences in terms of the intensity of somatic anxiety experienced; however, the challenge group reported experiencing lower levels of cognitive anxiety than the threat group. These findings are consistent with previous research demonstrating that a threat state is associated with greater cognitive anxiety (e.g., Quested et al., 2011). The IAMS data also revealed that the challenge group interpreted the cognitive anxiety they experienced as more facilitative for their performance and the somatic anxiety they experienced as less debilitative for their performance compared to the threat group. These findings are also congruent with previous research showing that a threat state is associated with a more debilitative interpretation of anxiety responses (e.g., Williams et al.,

2010). Mediation analyses revealed a small suppression effect for somatic anxiety direction. Although a challenge state led to a more facilitative interpretation of somatic anxiety symptoms, this in turn led to poorer performance. This unexpected finding is inconsistent with our hypotheses and may be an artefact due to Type 1 error (MacKinnon et al., 2000). Future research should further investigate how challenge and threat states impact performance via emotional mechanisms.

Challenge and threat states were also associated with different movement patterns. The putting kinematic data revealed that, compared to the threat group, the challenge group displayed lower lateral, vertical, and back-and-forth clubhead acceleration as well as lower peak acceleration and less root mean square jerk. This movement pattern is more consistent with the movement pattern displayed by expert golfers (see Sim & Kim, 2010). The lower lateral (X-axis) acceleration suggests that the challenge group kept the clubhead more reliably aligned with the hole and avoided pushing or pulling putts, whilst the lower vertical (Y-axis) acceleration implies that the challenge group kept the clubhead more parallel to the ground and avoided imparting top or backspin on the ball. The lower back-and-forth (Z-axis) acceleration, peak acceleration and root mean square jerk suggests that the challenge group performed with a smoother putting stroke and contacted the ball with less impact velocity, avoiding putts that were grossly over hit. Collectively, these findings support our hypotheses and add to previous research demonstrating that challenge and threat states can have divergent effects on movements (e.g., Mendes et al., 2007). Importantly, mediation analyses confirmed that all five of the putting kinematic variables mediated between-group differences in

performance, suggesting that challenge and threat states predominantly impact upon performance by influencing the quality of task-related movements.

A challenge state is said to result in more effective attention compared to a threat state (Jones et al., 2009). The quiet eye duration data supports this contention. As hypothesised, the challenge group displayed longer quiet eye durations than the threat group, a characteristic of more effective gaze behaviour and attentional control in aiming tasks (Mann et al., 2007). By holding longer quiet eye durations on the ball, the challenge group may have extended the time in which the task-relevant information gathered by preparatory fixations was processed and used to select, fine-tune and program the motor response (Mann et al., 2011). This may have increased the likelihood of correct decisions (e.g., distance to the hole) and accurate performance. However, mediation analysis revealed that quiet eye duration did not mediate between-group differences in performance. Thus, although challenge and threat states appear to differentially impact the efficiency of visual attentional control these differences did not appear to significantly influence performance on the motor task.

It has been suggested that muscular tension is likely to be greater during a threat state than a challenge state (Wright & Kirby, 2003), however, to date, no studies have examined this proposition. The muscle activity data provides some support for this proposition. Although no differences in muscle activity existed between the groups prior to movement initiation or during the backswing, the challenge group exhibited lower extensor carpi radialis activity during the foreswing and after putter-ball contact compared to the threat group. Given that previous research has shown that lower activation of task-relevant

muscles is associated with successful performance (e.g., Lay et al., 2002), the muscle activity pattern exhibited by the challenge group may be considered more effective for golf putting performance than the pattern exhibited by the threat group. Mediation analyses revealed that no muscle activity variable mediated between-group differences in performance. Therefore, although challenge and threat states appear to have divergent effects on muscle activity, these differences did not appear to impact upon task performance.

The findings of the present study have some important implications. Specifically, from a theoretical perspective, the findings imply that the BPSM (Blascovich, 2008a) may provide a useful framework by which performance variability under stress can be examined. Furthermore, the findings suggest that interventions aimed at modifying the way in which individuals evaluate highly demanding and stressful tasks could significantly impact upon performance. Encouraging individuals to evaluate demanding tasks more adaptively, as a challenge rather than a threat, should facilitate more favourable emotional, attentional, kinematic, and physiological responses that ultimately benefit performance. Moreover, given that the cardiovascular response associated with a threat state is considered to have deleterious consequences for health when frequently experienced, such interventions may also have important health implications (Blascovich, 2008b).

A challenge state may be fostered by reducing the evaluated demands of the task or by increasing the actual or evaluated resources of the individual. Indeed, the findings of the present study and previous research suggest that such alterations could be made with an intervention as subtle and inexpensive as manipulating the way the task is framed (e.g., Feinberg & Aiello, 2010).

Thus, coaches, managers, and sport psychologists should be mindful of the impact their instructions have on task performance and individuals' emotional, attentional, behavioural, and physiological responses. Tasks should be framed in a manner consistent with challenge, as this has the potential to lead to performance facilitation and more favourable responses.

Despite the encouraging findings, the present study is not without its limitations. Firstly, the adoption of a between-subjects design and the absence of a baseline performance condition may be viewed as potential limitations. However, previous challenge and threat research has successfully utilised a between-subjects design (e.g., Feinberg & Aiello, 2010). Furthermore, previous research has demonstrated that the amount of practice or exposure to a task dampens cardiovascular responses and that prior task performance has a significant impact on demand/resource evaluations (Kelsey, Blascovich, Tomaka, Leitten, Schneider, & Wiens, 1999; Quigley, Feldman Barrett, & Weinstein, 2002). Secondly, the use of multiple simple mediation analyses on many variables may be viewed as a potential limitation of the present study. Future research is therefore encouraged to develop and test more complex mediation models (e.g., challenge/threat => emotions => muscle activity => kinematics => performance) using statistical techniques such as structural equation modelling, although this would require a greater sample size than the present study to obtain adequate statistical power. The findings from such research are likely to substantially aid the development of theory and effective theory-based interventions.

Moreover, the fact that the present study only examined the effects of challenge and threat states over six trials may be viewed as a potential

limitation. However, various authors have noted the dynamic nature of demand and resource evaluations and how these evaluations tend to fluctuate during task performance as more information becomes available (Blascovich, 2008a; Jones et al., 2009; Quigley et al., 2002). Thus, whilst some individuals may begin by evaluating a task as a threat this may change as early as after the first putt and the task might become evaluated as less threatening or even challenging, and vice versa. This re-evaluation may have an impact upon performance and so the present study adopted a small number of trials to reduce the likelihood of re-evaluation. Finally, the present study only examined the effects of challenge and threat states on individuals performing a novel motor task. Thus, the findings of the present study have limited generalisability. Future research should aim to investigate the effects of challenge and threat states on the performance of experienced individuals and whether the underlying mechanisms are consistent with those highlighted in the present study.

To conclude, the results demonstrate that challenge and threat states can have an immediate effect on motor task performance, with a challenge state resulting in superior performance relative to a threat state. Mediation analyses revealed that challenge and threat states influence performance via kinematic mechanisms, impacting the quality of task-related movements. The results highlight that the performance of a demanding and novel task can be facilitated by providing individuals with instructions that foster a challenge state, deemphasising the difficulty of the task, and encouraging individuals to evaluate that they possess the resources required to cope with the task demands.

Chapter two demonstrated that challenge and threat states can have a direct effect on the performance of a novel motor task, with a challenge state leading to better performance than a threat state. Furthermore, chapter two showed that challenge and threat states can have divergent effects on individuals' emotions, attention, movements, and muscle activity. Chapter two also revealed that challenge and threat states influence performance by impacting the quality of task-related movements, with a challenge state resulting in more optimal movements. Chapter three extends chapter two across two studies. The first study examines the immediate effect of challenge and threat states on the performance of experienced golfers in a real pressurised competition. The second study builds on chapter two by investigating the direct impact of challenge and threat states on the motor performance of experienced golfers performing a golf putting task and by identifying the potential mechanisms through which challenge and threat states operate in this sample.

CHAPTER 3: CHAMP OR CHUMP? CHALLENGE AND THREAT STATES DURING PRESSURISED COMPETITION

3.1 Introduction

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

The BPSM (Blascovich, 2008a), a model central to the theory of challenge and threat states in athletes (TCTSA; Jones et al., 2009), suggests that how individuals respond in a motivated performance situation (e.g., exam, speech, sport competition) is determined by their evaluations of situational demands and personal coping resources. Importantly, these evaluations can be conscious, unconscious (i.e., automatic), or both, and are only formed when an individual is actively engaged in the situation (evidenced by increases in heart rate and decreases in cardiac pre-ejection period; Seery, 2011). When personal coping resources are evaluated as sufficient to meet or exceed situational demands, a challenge state occurs. Conversely, when personal coping resources are evaluated as insufficient to meet situational demands, a threat state ensues (Seery, 2011). Research employing self-report measures has offered support for these divergent demand/resource evaluations (e.g., Tomaka et al., 1997). Despite their discrete labels, challenge and threat are not

considered dichotomous states but instead, as two anchors of a single bipolar continuum. Thus, research has often examined relative differences in challenge and threat (i.e., greater vs. lesser challenge or threat) rather than absolute differences (Seery, 2011).

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

According to the BPSM (Blascovich, 2008a) and TCTSA (Jones et al., 2009), a challenge state should lead to better performance than a threat state. A number of empirical and predictive studies have supported this assumption (Mendes et al., 2007; Seery et al., 2010; Turner et al., 2012). For example, Blascovich and colleagues found that exhibiting a challenge state in response to

a sport-relevant speech task was associated with superior real-world performance, four to six months later during the competitive season (Blascovich et al., 2004). However, to date, no research has examined whether challenge and threat states (or underlying demand/resource evaluations), assessed immediately before a real pressurised competition, are associated with varying levels of performance. Furthermore, no research has examined the immediate impact of these states on the motor performance of experienced individuals. The present research was designed to shed light on these issues.

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

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

Thirdly, the behaviours and movements accompanying challenge and threat states are said to differ (Blascovich, 2008a; Jones et al., 2009). Several studies have supported this prediction (O'Connor et al., 2010; Weisbuch et al., 2009). For instance, Mendes et al. (2007) found that, compared to a threat state, a challenge state resulted in more effective movements during an interaction task, including less freezing, avoidance posture, and more smiling. Thus, a challenge state might lead to superior performance by promoting movement patterns that are more likely to result in successful task completion. Finally, it is assumed that a challenge state may be associated with less muscular tension than a threat state (Wright & Kirby, 2003). To date, little

research has examined this assumption. Given that successful performance has been linked with lower muscular activation (Lay et al., 2002), a challenge state could cause better performance by encouraging lower activation of task-relevant muscles. Despite a number of possible mechanisms being suggested, no studies have examined the underlying mechanisms that might explain the effects of challenge and threat states on the performance of experienced performers.

Drawing on the research outlined above, the aim of the present research was to investigate the immediate effect of challenge and threat states on the performance of experienced golfers during a real golf competition and a laboratory-based golf putting task. Specifically, the aim of study 1 was to examine the relationship between pre-competition challenge and threat states (assessed via demand/resource evaluations) and competitive performance. It was hypothesised that evaluating the competition as a challenge (i.e., resources match or exceed demands) would predict better performance compared to evaluating it as a threat (i.e., demands exceed resources). This relationship was then investigated in more detail in study 2 using a laboratory-based task, the controlled context allowing for a more powerful test of the potential processes underpinning performance. The aim of study 2 was to examine the immediate impact of challenge and threat states on the golf putting performance of experienced golfers and to identify the possible mechanisms through which these states operate (emotional, attentional, kinematic, and/or physiological). It was predicted that, compared to the threat group, the challenge group would exhibit relatively higher cardiac output and lower total peripheral resistance. Additionally, it was predicted that the challenge group would outperform the threat group during the golf putting task; report a more favourable emotional

response (i.e., less cognitive and somatic anxiety, and more facilitative interpretations of anxiety symptoms); and display more effective attention (i.e., less conscious processing and longer quiet eye durations); putting kinematics (i.e., lower clubhead acceleration and jerk); and muscle activation (i.e., lower extensor carpi radialis activity). Finally, in order to examine the potential mechanisms through which challenge and threat states might influence performance, mediation analyses were performed (Hayes & Preacher, 2013).

3.2 Study 1

3.2.1 Method

3.2.1.1. Participants

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

3.2.1.2. Measures

3.2.1.2.1 Demand/Resource Evaluations. Demand and resource evaluations were measured using two items from the cognitive appraisal ratio (Tomaka et al., 1993). Importantly, this measure has been used frequently and

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

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

3.2.1.3 Procedure

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

3.2.2 Results and Discussion

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

The present study is the first to demonstrate that demand/resource evaluations (underpinning challenge and threat states) made immediately prior

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

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

mechanisms through which challenge and threat states impact performance were also investigated.

3.3 Study 2

3.3.1 Method

3.3.1.1 Participants

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

3.3.1.2 Measures

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

3.3.1.2.2 Cognitive and Somatic State Anxiety. The immediate anxiety measurement scale (Thomas et al., 2002) was used to measure participants'

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

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

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

3.3.1.2.5 Quiet Eye Duration. An Applied Science Laboratories (ASL; Bedford, MA, USA) Mobile Eye Tracker was used to measure gaze (see section 2.2.2.4 for a detailed description of how gaze is recorded using this device). The

quiet eye duration was operationally defined as the final fixation towards the ball prior to the initiation of the backswing (Vickers, 2007). Quiet eye onset occurred before the backswing and quiet eye offset occurred when the gaze deviated off the fixated object by 1° or more, for greater than 100 ms (Vickers, 2007). A fixation was defined as a gaze maintained on an object within 1° of visual angle for a minimum of 100 ms (Vickers, 2007).

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

3.3.1.2.6 Cardiovascular Measures. Heart rate and cardiac output were estimated using a non-invasive impedance cardiograph device (Physioflow, PF05L1, Manatec Biomedical, Paris, France). Following procedures described in section 2.2.2.5, participants were fitted with the Physioflow device, which was then calibrated. Heart rate and cardiac output were estimated continuously during baseline (5 minutes) and post-manipulation (1 minute) time periods. Participants remained seated, still, and quiet throughout both time periods

which were separated by approximately 90 seconds. Reactivity, or the difference between the final minute of baseline and the minute post-manipulation, was examined for all cardiovascular variables.

Although heart rate and cardiac pre-ejection period are both considered markers of task engagement (with greater increases in heart rate and decreases in cardiac pre-ejection period reflecting greater task engagement; Seery, 2011), only heart rate was used in the present study as the Physioflow does not allow cardiac pre-ejection period to be estimated. Cardiac output and total peripheral resistance are cardiovascular indices that differentiate challenge and threat states; with a challenge state characterised by higher cardiac output and lower total peripheral resistance (Seery, 2011). While cardiac output was estimated directly by the Physioflow, total peripheral resistance was calculated using the formula: [mean arterial pressure x 80 / cardiac output] (Sherwood et al., 1990). Mean arterial pressure was calculated using the formula: [(2 x diastolic blood pressure) + systolic blood pressure / 3] (Cywinski, 1980).

3.3.1.2.7 Putting Kinematics. Putting kinematic data was recorded using a tri-axial accelerometer (LIS3L06AL, ST Microelectronics, Geneva, Switzerland) and bespoke buffer amplifier (with a frequency response of DC to 15 Hz) mounted to the rear of the clubhead. A microphone (B5 Condenser, Behringer, Germany) connected to a mixing desk (Eurorack UB802, Behringer, Germany) detected the putter-ball contact on each trial. Signals were digitised at 2500 Hz. A computer program determined clubhead kinematics for each putt from initiation of the foreswing until the putter contacted the ball. Average acceleration of the clubhead in three axes (X = lateral, Y = vertical, and Z = back-and-forth) was calculated and enabled the assessment of clubhead

orientation, clubhead height, and impact velocity, respectively. Furthermore, peak acceleration and root mean square jerk were also calculated for the Z-axis as the main axis involved in golf putting. The values from all trials were averaged to provide a test mean value for each kinematic variable (as Cooke et al., 2010; Moore et al., 2012).

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

3.3.1.3 Procedure

Firstly, after providing demographic information (age, handicap, experience, and rounds per week), the ASL Mobile eye-tracker and

physiological recording equipment were fitted. Subsequently, 5 minutes of baseline cardiovascular data was recorded. Next, participants received their respective manipulation (challenge or threat; see section 3.3.1.4). Cardiovascular data was then recorded for a 1 minute period. Participants remained seated, still, and quiet throughout this process. Afterward participants completed the demand resource evaluation score and immediate anxiety measurement scale. Following this, participants completed the task which consisted of six straight putts from three, 2.44 m locations to a half-size hole (diameter = 5.4 cm) on an artificial putting green (length = 6 m, width = 2.5 m; Stimpmeter reading = 3.28 m). A half-size hole was used to aid the effectiveness of the threat manipulation instructions (e.g., help ensure that participants believed that the task was difficult). All participants used the same golf putter (Sedona 2, Ping, Phoenix, AZ) and regular-size (diameter = 4.27 cm) white golf balls. Performance, gaze behaviour, putting kinematic, and muscle activity data were continuously recorded throughout all putts. Finally, participants completed the conscious processing measure, had all equipment removed, and were thanked and debriefed about the aims of the study.

3.3.1.4 Challenge and Threat Manipulations

Participants were randomly assigned to the two experimental groups using a random number generator (www.random.org) until an equal number of participants were in each group (Challenge n = 30; Threat n = 30). Instructional sets adapted from previous research were delivered verbally by the experimenter in order to manipulate participants into either a challenge or threat state (e.g., Feinberg & Aiello, 2010). To encourage task engagement, the instructions given to both groups emphasised the importance of the task; that

their score would be compared against others taking part (published leader board); that the task was going to be objectively evaluated (digital video camera); that participants who performed poorly would be interviewed; and that participants who performed well would receive a financial reward (top 5 performers awarded cash prizes of £50, £25, £20, £15, and £10, respectively[2]). The challenge instructions encouraged participants to perceive the task as a challenge to be met and overcome, to think of themselves as someone capable of meeting that challenge, and highlighted that previous participants had performed well on the task. In contrast, the threat instructions focused on the task's high degree of difficulty and emphasised that previous participants had struggled to perform well on the task. Thus, the instructions aimed to promote challenge and threat states by influencing both evaluations of task demands and personal coping resources (see Appendix 3).

3.3.1.5 Statistical Analysis

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

calculated in order to control for baseline values. Cardiac output was assigned a weight of +1 and total peripheral resistance a weight of -1, such that a larger value corresponded with greater challenge (as Seery et al., 2009). To compare the groups, an independent *t*-test was conducted on the challenge and threat index data.

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

3.3.2 Results

3.3.2.1 Demographics

There was no significant differences between the groups in terms of age, $t(58) = 1.37$, $p = .176$, $d = 0.36$, handicap, $t(58) = 0.04$, $p = .968$, $d = 0.01$, experience, $t(58) = 1.50$, $p = .140$, $d = 0.39$, or rounds per week, $t(58) = 0.03$, $p = .978$, $d = 0.01$. Thus, the randomisation process was effective and the groups were equated prior to receiving the manipulation instructions (see Table 3.1).

3.3.2.2 Manipulation Checks

In the sample as a whole, heart rate increased significantly from baseline by an average of 5.25 beats per minute ($SD = 4.97$), $t(58) = 8.04$, $p < .001$, $d = 2.11$, confirming task engagement and allowing the examination of challenge and threat states[3,4]. Compared to the threat group, the challenge group exhibited a significantly larger challenge and threat index value, $t(55) = 2.11$, $p = .040$, $d = 0.57$[5]. Furthermore, the challenge group reported a significantly higher demand resource evaluation score than the threat group, $t(58) = 5.42$, $p < .001$, $d = 1.42$ (see Table 3.1).

3.3.2.3 Performance

In contrast to the threat group, the challenge group holed a significantly higher percentage of putts, $t(58) = 2.41$, $p = .019$, $d = 0.63$. Moreover, the challenge group achieved a significantly lower performance error than the threat group, $t(56) = 2.61$, $p = .012$, $d = 0.70$[6] (see Table 3.1).

3.3.2.4 Cognitive and Somatic Anxiety

The challenge group reported experiencing significantly lower levels of cognitive, $t(49.80) = 4.89$, $p < .001$, $d = 1.39$, and somatic, $t(56) = 2.69$, $p = .009$, $d = 0.72$[7], anxiety than the threat group. Furthermore, compared to the threat group, the challenge group interpreted the cognitive, $t(58) = 2.29$, $p =$

.026, d = 0.60, and somatic, $t(58)$ = 2.83, p = .006, d = 0.74, anxiety they experienced as significantly more facilitative for their performance (see Table 3.1).

3.3.2.5 Conscious Processing

The challenge group reported significantly less conscious processing than the threat group, $t(58)$ = 3.77, p < .001, d = 0.99 (see Table 3.1).

3.3.2.6 Quiet Eye Duration

The challenge group displayed significantly longer quiet eye durations than the threat group, $t(46)$ = 4.72, p < .001, d = 1.39 (see Table 3.1).

3.3.2.7 Putting Kinematics

There was no significant difference between the groups in terms of X-axis (lateral) acceleration, $t(58)$ = 1.10, p = .277, d = 0.29; Y-axis (vertical) acceleration, $t(58)$ = 1.49, p = .143, d = 0.39; Z-axis (back-and-forth) acceleration, $t(57)$ = 1.51, p = .138, d = 0.40[8]; peak acceleration, $t(55)$ = 0.02, p = .983, d = 0.01[9]; or root mean square jerk, $t(58)$ = 1.09, p = .283, d = 0.29 (see Table 3.1).

3.3.2.8 Muscle Activity

There was no significant difference between the groups in terms of muscle activity during pre-initiation, $t(48.74)$ = 0.61, p = .543, d = 0.17; backswing, $t(55)$ = 0.19, p = .853, d = 0.05[10]; foreswing, $t(56)$ = 0.54, p = .594, d = 0.14; or post-contact, $t(56)$ = 0.60, p = .549, d = 0.16[11] (see Table 3.1).

Table 3.1 Mean (*SD*) demographic, manipulation check, performance, cognitive and somatic anxiety, conscious processing, gaze, putting kinematic, and muscle activity data for challenge and threat groups.

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

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

3.3.2.9 Mediation Analyses

To test if the relationship between group and performance was mediated by any of the process variables, experimental group (coded: challenge = 1, threat = 0) was entered as the independent variable, either percentage of putts holed or performance error was entered as the dependent variable, and a number of potential mediators were entered separately. Based on a 10,000 sampling rate, the results from bootstrapping revealed no significant indirect effects for any of the process variables with either percentage of putts holed or performance error entered as the dependent variable. This was because the 95% confidence intervals for all mediation analyses contained zero (see Tables 3.2 and 3.3). Thus, none of the process variables mediated the relationship between experimental group and performance.

Table 3.2 Mediation results for all cognitive and somatic anxiety, conscious processing, and gaze variables with experimental group entered as the independent variable and percentage of putts holed entered as the dependent variable.

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

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

Table 3.3 Mediation results for all cognitive and somatic anxiety, conscious processing, and gaze variables with experimental group entered as the independent variable and performance error entered as the dependent variable.

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

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

3.3.3 Discussion

Challenge and threat states were successfully manipulated via task instructions (as Tomaka et al., 1997). Specifically, the challenge group reported a positive mean demand resource evaluation score, indicating that this group evaluated that they had sufficient resources to cope with the demands of the task. In contrast, the threat group reported a negative mean demand resource evaluation score, indicating that this group evaluated that they had insufficient resources to cope with task demands. In line with the predictions of the BPSM (Blascovich, 2008a) and TCTSA (Jones et al., 2009), these divergent demand/resource evaluations led to different cardiovascular responses. Although the whole sample showed increases in heart rate reflecting task

engagement (a pre-requisite of challenge and threat states; Seery, 2011), the challenge group displayed a larger index value than the threat group. Thus, the challenge group exhibited a cardiovascular response consisting of relatively higher cardiac output and lower total peripheral resistance compared to the threat group (Seery, 2011).

Interestingly, while both groups were engaged in the task, the challenge group displayed greater increases in heart rate than the threat group, suggesting that they were more engaged in the pressurised task (see note 4). This finding can also be interpreted in terms of the motivation intensity theory developed by Wright and colleagues (Gendolla & Wright, 2012; Wright & Kirby, 2001). According to this theory, individuals tend to exhibit larger increases in heart rate when they invest greater effort during both cognitive and motor tasks. Given that the cardiovascular data in the present study were recorded prior to (when participants were thinking about the upcoming task), rather than during, the pressurised task, the greater increase in heart rate displayed by the challenge group might be due to this group investing more mental effort into preparing for the pressurised task than the threat group, ultimately benefitting their performance. Indeed, this would be an interesting explanation for future research to investigate (Seery, 2013).

As predicted by the BPSM (Blascovich, 2008a) and TCTSA (Jones et al., 2009), the challenge group outperformed the threat group in the golf putting task, successfully holing a higher percentage of putts and achieving a lower performance error. However, it should be noted that the percentage of putts successfully holed was low for both groups, reflecting the high degree of difficulty of the task (i.e., half-size hole). Nonetheless, these results equate to

medium to large effect sizes and are congruent with previous research demonstrating that a challenge state typically facilitates performance whilst a threat state generally hinders performance (Blascovich et al., 2004; Mendes et al., 2007; Seery et al., 2010; Turner et al., 2012). The present study extends this research and is the first to demonstrate that challenge and threat states can have an immediate and direct effect (i.e., ~ 2 minutes post-manipulation) on the motor performance of experienced individuals, with a challenge state resulting in superior performance compared to a threat state.

As hypothesised, the emotional states emanating from challenge and threat states differed. Congruent with previous research (e.g., Williams et al., 2010), the challenge group reported experiencing less cognitive and somatic anxiety than the threat group. Furthermore, the challenge group interpreted the anxiety they experienced as facilitative for their performance, whilst the threat group interpreted the anxiety they felt as debilitative for their performance. However, mediation analyses revealed that none of the emotional variables mediated the effect of experimental group on either performance measure (percentage of putts holed or performance error). Thus, although challenge and threat states led to different emotional responses, these differences did not explain why the challenge group performed better than the threat group.

Challenge and threat states had different effects on attention. As predicted, the challenge group reported less conscious processing than the threat group. This suggests that the challenge group directed less attention inward, in an attempt to consciously control the mechanics of skill execution in a step-by-step manner. Such 'reinvestment' has been shown to have a detrimental effect on the performance of individuals performing automatized

skills under pressure (Masters & Maxwell, 2008). Additionally, the challenge group displayed longer quiet eye durations than the threat group. Longer quiet eye durations accompany optimal performance under pressure and are proposed to benefit pressurised performance by extending a critical period of time during which the motor response is selected, fine-tuned, and programmed (Vine et al., 2012). Although challenge and threat states influenced attention differently, these differences failed to explain the performance differences between the groups. Mediation analyses revealed that neither attentional measure mediated the group-performance relationship.

Contrary to predictions, there were no significant differences between the groups in terms of putting kinematics or extensor carpi radialis activation. These unexpected findings may be explained by the sample studied. Indeed, the present study examined a sample of experienced golfers and recent research has identified that the control of the putting stroke and muscle activity patterns may have less influence on the putting proficiency of experienced golfers compared to other factors such as the ability to accurately judge the speed of the putting green (Cooke et al., 2011; Karlsen & Nilsson, 2008; Karlsen, Smith, & Nilsson, 2008).

Despite the interesting findings, the limitations inherent in the present study must be acknowledged. Firstly, a between-subjects design was employed and baseline performance was not assessed (unlike Turner et al., 2012). However, it should be noted that the amount of exposure to a task can dampen cardiovascular responses and that prior task performance can influence subsequent demand and resource evaluations (Kelsey et al., 1999; Quigley et al., 2002). Thus, individuals who previously performed poorly on a task may be

more likely to evaluate the task as a threat in the future compared to individuals who performed well on the task. Additionally, the effects of challenge and threat states were only investigated over six trials. Although this may cause some concern, demand and resource evaluations are said to be dynamic and fluctuate during a task as new information becomes available (Blascovich, 2008a; Jones et al., 2009; Quigley et al., 2002). Therefore, although individuals may evaluate a task as a threat at first, this might alter after one or two trials, causing individuals to evaluate the task as less threatening or even challenging, and vice versa. Performance may be influenced by such re-evaluation and so few trials were employed to decrease the impact of re-evaluation. However, the complex and reciprocal relationship between demand/resource evaluations and performance would be an interesting avenue for future research.

3.4 General Discussion

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

Study 1 revealed that demand and resource evaluations (determining challenge and threat states) made immediately prior to a real pressurised competition can significantly impact upon competitive performance. Specifically,

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

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

possible underlying process is speculative and it remains for future research to explore this and other potential explanations.

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

The limitations of the present research highlight some directions for future research. Firstly, the antecedents of challenge and threat states were not assessed in either study but could be examined in future research. Indeed, a range of factors have been proposed to influence the demand/resource

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

To conclude, the results of the present research demonstrate that challenge and threat states (assessed via subjective and objective measures) can have an immediate effect on the motor performance of experienced individuals in both real pressurised competition and a laboratory-based task. In each setting, a challenge state was associated with superior competitive performance compared to a threat state. Furthermore, in a laboratory-based context, a challenge state was associated with more favourable emotional

responses and attentional processes. Collectively, these results suggest that by using interventions that encourage individuals to evaluate that they possess the resources to cope with the demands of a pressurised competition, practitioners could develop future champs rather than chumps.

3.5 Footnotes

1. Competition standard scratch is employed on the day of competition to quantify the influence of weather and course conditions on the scoring ability of the golfers and to make adjustments to their handicaps. This system is used in the United Kingdom and is equivalent to the slope rating system used in North America.

2. It should be noted that the cash prizes were given to the top 5 performing participants.

3. Heart rate reactivity data from 1 participant was identified as an outlier and excluded from all analyses.

4. Heart rate increased significantly from baseline for both the challenge group (M = 8.15 bpm, SD = 4.64), $t(29)$ = 9.64, $p < .001$, d = 3.58, and the threat group (M = 2.13 bpm, SD = 3.10), $t(27)$ = 3.64, p = .001, d =1.40.

5. Challenge and threat index data from 2 participants were deemed outliers and removed from all analyses.

6. Performance error data from 2 participants were identified as outliers and excluded from all analyses.

7. Somatic anxiety intensity data from 2 participants were deemed outliers and removed from all analyses.

8. Z-axis acceleration data from 1 participant was identified as an outlier and excluded from all analyses.

9. Peak acceleration data from 3 participants were deemed outliers and removed from all analyses.

10. Pre-initiation and backswing muscle activity data from 3 participants were identified as outliers and excluded from all analyses.

11. Backswing and post-contact muscle activity data from 2 participants were deemed outliers and removed from all analyses.

Chapter three demonstrated that challenge and threat states can have direct effects on the motor performance of experienced individuals in a real pressurised competition. A challenge state (assessed via a subjective measure) predicted superior competitive performance relative to a threat state. In addition, chapter three showed that a challenge state (assessed via subjective and objective measures) led to more accurate performance than a threat state among experienced golfers performing a pressurised golf putting task. Finally, chapter three revealed that although challenge and threat states had different effects on emotions and attention, these variables could not explain how a challenge state resulted in superior performance compared to a threat state. Chapter four builds on chapter three by focusing on the antecedents of challenge and threat states. Given the divergent effects challenge and threat states have on performance, it is important to identify the antecedents that should be focused on in interventions designed to promote a challenge state and deter a threat state. More specifically, chapter four examines the influence of two antecedents proposed by the BPSM, perceptions of required effort and support availability, on demand/resource evaluations, challenge and threat states, and motor performance.

CHAPTER 4: EXAMINING THE ANTECEDENTS OF CHALLENGE AND THREAT STATES: THE INFLUENCE OF PERCEIVED REQUIRED EFFORT AND SUPPORT AVAILABILITY

4.1 Introduction

Individuals from a range of contexts (e.g., sport, surgery, military, and aviation) are often required to perform important tasks under extreme stress. As individuals do not respond to stress in a uniform manner, it is interesting to consider what factors cause these different stress responses. One theoretical framework that offers an important insight into how individuals respond to stress is the biopsychosocial model (BPSM) of challenge and threat (Blascovich, 2008a). Despite recent research examining this model, particularly the consequences of challenge and threat states (e.g., Turner et al., 2012), limited research has explicitly examined the antecedents that are proposed by this model to influence these states. Thus, the present study examined the impact of two antecedents of challenge and threat states proposed by the BPSM; perceived required effort and support availability.

Rooted in the work of Lazarus and Folkman (1984) and Dienstbier (1989), the BPSM contends that an individual's stress response during a motivated performance situation (e.g., exam, speech, competitive task) is determined by their evaluations of situational demands and personal coping resources (Blascovich, 2008a). These evaluations are said to be dynamic, relatively automatic (i.e., unconscious), and only occur when an individual is actively engaged in a situation (indexed by increases in heart rate and decreases in cardiac pre-ejection period; Seery, 2013). The BPSM specifies that when evaluated personal coping resources match or exceed situational

demands, a challenge state occurs. Conversely, when evaluated situational demands outweigh personal coping resources, a threat state ensues (Blascovich, 2008a). Despite their discrete labels, challenge and threat are considered two anchors of a single bipolar continuum such that relative differences in challenge and threat (i.e., greater vs. lesser challenge or threat) are meaningful and commonly examined by researchers (Seery, 2011).

According to the BPSM, the demand/resource evaluation process triggers distinct neuroendocrine and cardiovascular responses (Blascovich, 2008a; Seery, 2011). During challenge and threat states, sympathetic-adrenomedullary activation is elevated. This activation increases blood flow to the brain and muscles due to higher cardiac activity and vasodilation of blood vessels via the release of catecholamines (epinephrine and norepinephrine). Importantly, during a threat state, pituitary-adrenocortical activation is also heightened. This dampens sympathetic-adrenomedullary activation and decreases blood flow due to reduced cardiac activity and diminished vasodilation (or even vasoconstriction) via the release of cortisol. Consequently, compared to a threat state, a challenge state is characterised by relatively higher cardiac output and lower total peripheral resistance, a cardiovascular response considered more efficient for energy mobilisation and action (Seery, 2011). These cardiovascular markers have been extensively validated in the literature (see Blascovich, 2008a for a review).

The BPSM suggests that a challenge state should lead to better task performance than a threat state (Blascovich, 2008a). Indeed, a number of predictive and empirical studies have offered support for this assumption using academic (e.g., Seery et al., 2010), cognitive (e.g., Gildea et al., 2007; Mendes et al., 2007; Turner et al., 2012), and motor (e.g., Blascovich et al., 2004; Turner

et al., 2013) tasks. For example, Vine and colleagues found that evaluating a novel (surgical) motor task as more of a challenge was associated with a cardiovascular response more indicative of a challenge state and superior performance (i.e., quicker completion times) compared to evaluating the task as more of a threat. Furthermore, after being trained to proficiency, the participants performed the same motor task under stressful conditions. The results revealed that evaluating the task as more of a challenge was again associated with better performance than evaluating the task as more of a threat (Vine et al., 2013).

The demand/resource evaluation process is complex and thus challenge and threat states can be influenced by many interrelated factors (Blascovich, 2014). For example, psychological and physical danger, familiarity, uncertainty, required effort, skills, knowledge and abilities, and the availability of external support have all been proposed to impact upon demand and/or resource evaluations (Blascovich, 2008a; Frings et al., 2014). The cardiovascular indices of challenge and threat states have been used to test various psychological theories including those related to inter-individual (e.g., social comparison; Mendes et al., 2001) and intra-individual (e.g., social power; Scheepers et al., 2012) processes. While the latter has inadvertently offered some potential antecedents, to date, no research has explicitly examined the effect of any of the antecedents proposed by the BPSM on demand/resource evaluations, challenge and threat states, and motor performance. This is surprising given the potential for such research to aid the development of the BPSM and help identify which factors are most crucial to target during interventions designed to facilitate challenge states in response to stressful tasks. Indeed, by promoting challenge states rather than threat states, these interventions are likely to have

beneficial effects on performance and long-term cardiovascular and mental health (see Blascovich, 2008b).

Two of these potential antecedents, perceived required effort and support availability, have been discussed in recent reviews (McGrath et al., 2011; Seery, 2013). Although research has shown that expending greater effort during a task is characterised by increased heart rate and systolic blood pressure (see Wright & Kirby, 2001), no research has examined if perceptions relating to the effort required to successfully complete an upcoming task influences the cardiovascular indexes of challenge and threat. As perceptions of required effort have been proposed to contribute to demand/resource evaluations, with greater perceived required effort leading to higher demand evaluations and lower resource evaluations, greater perceived required effort could cause a cardiovascular response more reflective of a threat state (i.e., relatively lower cardiac output and higher total peripheral resistance; Blascovich & Mendes, 2000; Seery, 2013). Furthermore, despite research demonstrating that cardiovascular reactivity (i.e., systolic and diastolic blood pressure) is reduced when social support is perceived to be available during a stressful task (see Uchino & Garvey, 1997), limited research has investigated the influence perceived support has on the cardiovascular markers of challenge and threat. As perceptions of available support have been proposed to influence demand/resource evaluations, with perceived support availability leading to lower demand evaluations and higher resource evaluations, perceived available support might lead to a cardiovascular response more indicative of a challenge state (i.e., relatively higher cardiac output and lower total peripheral resistance; McGrath et al., 2011).

The aim of the present study was to examine the impact of perceived required effort and support availability on demand/resource evaluations, challenge and threat states, and motor task (laparoscopic surgery) performance. It was hypothesised that, compared to participants in the high required effort condition, participants in the low required effort condition would have more favourable demand/resource evaluations (i.e., resources outweighed demands), a cardiovascular response more reflective of a challenge state (i.e., relatively higher cardiac output and lower total peripheral resistance), and superior task performance (i.e., quicker completion time). Furthermore, it was hypothesised that, compared to participants in the no support available condition; participants in the support available condition would have more favourable demand/resource evaluations, a cardiovascular response more reflective of a challenge state, and superior task performance. Due to the absence of prior research investigating the antecedents of challenge and threat states, no predictions were made for the interaction effect of perceived required effort and support availability.

4.2 Method

4.2.1 Participants

One hundred and twenty undergraduate students (59 women, 61 male; 109 right-handed, 11 left-handed) with a mean age of 21.57 ($SD = 2.99$) agreed to participate. All participants reported having no prior experience of laparoscopic surgery. Furthermore, all participants declared that they did not smoke, were free of illness or infection, and had normal or corrected vision, no known family history of cardiovascular or respiratory disease, had not performed vigorous exercise or ingested alcohol for 24 hours prior to testing,

and had not consumed food and/or caffeine for 1 hour prior to testing. Participants were tested individually. The study was approved by the institutional ethics committee and written informed consent was obtained from all participants.

4.2.2 Measures

4.2.2.1 Perceived Required Effort and Support Availability

In order to assess whether perceptions of required effort and support availability were successfully manipulated, participants were asked "How much effort do you think will be required to complete the surgical task?" and "How much support do you think will be available during the surgical task?" respectively. Both items were rated using a 7-point Likert scale anchored between *no effort (= 1)* and *extreme effort (= 7)* for perceived required effort, and *no support (= 1)* and *a lot of support (= 7)* for perceived support availability.

4.2.2.2 Demand/Resource Evaluations

Two items from the cognitive appraisal ratio (Tomaka et al., 1993) were employed to measure demand/resource evaluations. One item assessed task demands ("How demanding do you expect the surgical task to be?") and another assessed personal coping resources ("How able are you to cope with the demands of the surgical task?"). Each item was rated using a 6-point Likert scale anchored between *not at all (= 1)* and *extremely (= 6)*. Although previous research has tended to calculate a ratio score by dividing evaluated demands by resources (e.g., Feinberg & Aiello, 2010), such a ratio is highly non-linear and is therefore inconsistent with the notion that challenge and threat states are two anchors of a single bipolar continuum (Seery, 2011). Thus, instead, a

demand resource evaluation score was calculated by subtracting demands from resources (range: -5 to +5), with a more positive score reflecting a challenge state and a more negative score reflecting a threat state (see Vine et al., 2013).

4.2.2.3 Cardiovascular Responses

Cardiovascular data was estimated using a non-invasive impedance cardiograph device (Physioflow, PF05L1, Manatec Biomedical, Paris, France). The theoretical basis for this device and its validity has been published previously (e.g., Charloux et al., 2000). The Physioflow measures impedance changes in response to a high frequency (75 kHz) and low-amperage (3.8 mA) electrical current emitted via electrodes. Following preparation of the skin, six spot electrodes (Blue Sensor R, Ambu, Ballerup, Denmark) were positioned on the thorax; two on the supraclavicular fossa of the left lateral aspect of the neck, two near the xiphisternum at the midpoint of the thoracic region of the spine, one on the middle of the sternum, and one on the rib closest to V6. After entering the participants' details (height, weight etc.), the Physioflow was calibrated over 30 heart cycles while participants sat still and quiet in an upright position. Three resting systolic and diastolic blood pressure values were taken (one prior to the 30 heart cycles, one during this time period, and another immediately after this time period) manually by a trained experimenter using an aneroid sphygmomanometer (ACCOSON, London, UK) and stethoscope (Master Classic II, Littmann, 3M Health Care, St. Paul, USA). The mean blood pressure values were entered into the Physioflow to complete the calibration procedure.

Participants' cardiovascular responses were estimated continuously during baseline (5 minutes) and post-manipulation (1 minute) time periods while

they remained seated, still, and quiet. It is important to note that while previous challenge and threat research has often measured cardiovascular data during tasks, this method was not employed in the present study due to concerns relating to movement artifacts (Blascovich & Mendes, 2000; Blascovich et al., 2004). Heart rate, the number of times the heart beats per minute, was estimated directly by the Physioflow. Heart rate reactivity (the difference between the final minute of baseline and the minute post-manipulation) was used to assess task engagement; with greater increases in heart rate reflecting greater task engagement (Seery, 2011). Cardiac output, the amount of blood in litres pumped by the heart per minute, was estimated directly by the Physioflow. Furthermore, total peripheral resistance, a measure of net constriction versus dilation in the arterial system, 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). Cardiac output and total peripheral resistance were used to differentiate challenge and threat states; with a challenge state characterised by higher cardiac output and lower total peripheral resistance (Seery, 2011).

4.2.2.4 Task Performance

The laparoscopic surgery task was performed on a 3-Dmed (Franklin, OH) standard minimally invasive training system with a joystick SimScope (a manoeuvrable webcam). The scene inside the training box was viewed on a monitor (via the webcam). A surgical tool was inserted through a port on the box allowing objects to be moved inside the box. Participants completed a ball pick and drop task, in which they had to move 6 foam balls (diameter = 5 mm) from

stems of varying heights into a cup, using a single tool (with their dominant hand). The balls had to be grasped and dropped into the cup individually and in a pre-specified order (see Vine et al., 2013 for a more detailed description and image of this system and task). Participants were informed to complete the task as quickly and as accurately (i.e., no dropped balls) as they could. Performance was assessed in terms of completion time, as this measure has been shown to differentiate varying levels of expertise in this task more precisely than other measures such as the number of balls knocked off or dropped (as Vine et al., 2013).

4.2.3 Procedure

Firstly, the participants were introduced to the experimenters (1 male aged 24 years and 2 females both aged 21 years) before providing written informed consent. Importantly, the experimenters were trained to ensure that their behaviours were consistent for all participants. The participants were then fitted with the Physioflow and Applied Science Laboratories (ASL) mobile eye tracker[1] by the two female experimenters who were blind to the participants' experimental condition until the manipulation instructions were given. Subsequently, 5 minutes of baseline cardiovascular data was recorded. Next, participants received their respective manipulation instructions from the male experimenter (see section 4.2.4.). Cardiovascular data was then recorded for a 1 minute period while participants reflected on these instructions and anticipated the upcoming task. Afterward, participants completed the various self-report measures before carrying out the ball pick and drop task. Task performance and gaze data were continuously recorded throughout the surgical

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[1] Gaze and tool movement data were recorded using the ASL system but are not reported.

task. Finally, following the removal of the Physioflow and ASL mobile eye tracker, participants were thanked and debriefed about the aims of the study.

4.2.4 Manipulation Instructions

Participants were randomly assigned to one of four experimental conditions: (1) low required effort - support available (LRE-SA); (2) low required effort - no support available (LRE-NSA); (3) high required effort - support available (HRE-SA); or (4) high required effort - no support available (HRE-NSA). Instructions adapted from previous research were used to engage participants with the task and to manipulate participants' perceptions of required effort and support availability (e.g., Uchino & Garvey, 1997). To ensure task engagement, all participants received instructions emphasising the importance of the task; that their score would be compared against other participants (published leader board); that the task would be objectively evaluated (digital video camera); that low performing participants would be interviewed; and that financial rewards would be given to high performing participants' (top 5 performers awarded cash prizes of £50, £25, £20, £15, and £10, respectively).

The low required effort instructions outlined that the task was straightforward, required little physical and mental effort, and would only take approximately 60 seconds to complete. In contrast, the high required effort instructions indicated that the task was difficult, required a great deal of physical and mental effort, and would take about 60 seconds to finish. The support available instructions indicated that the experimenters would be in the room while the participant performed the task and that if the participant required assistance for any reason or had any questions regarding the task, the participant could ask the experimenters. Conversely, the no support available

instructions emphasised that the experimenters would be in the room while the participant performed the task but that if the participant needed any assistance or had any questions regarding the task, the participant could not ask the experimenters (see Appendix 4). It is important to note that despite the latter instructions, no participants in any of the experimental conditions asked for assistance or help during completion of the task.

4.2.5 Statistical Analysis

Prior to the main statistical analyses, outlier analyses were conducted. Ten univariate outliers (values more than 3.3 standard deviation units from the grand mean; Tabachnick & Fidell, 1996) were identified and winsorised by changing the deviant raw score to a value 1% larger or smaller than the next most extreme score (as Shimizu et al., 2011). Following this analysis, all variables were normally distributed except the perceived support availability data (z-scores for skewness and kurtosis exceeded 1.96).

The heart rate reactivity data were subject to a dependent *t*-test to assess task engagement and establish that in the sample as a whole, heart rate increased significantly from baseline (as Seery et al., 2009). An effect size was calculated using Cohen's *d*. In order to examine relative differences in challenge and threat states, an index was created by converting each participant's cardiac output and total peripheral resistance residualised change scores into z-scores and summing them. Residualised change scores were calculated in order to control for baseline values. Cardiac output was assigned a weight of +1 and total peripheral resistance a weight of -1, such that a larger value corresponded with greater challenge (as Seery et al., 2009).

To examine the effects of perceived required effort and support availability a series of 2 (perceived required effort; high required effort, low required effort) x 2 (perceived support availability; support available, no support available) univariate analysis of variance (ANOVA) were conducted with perceived required effort, demand resource evaluation score, challenge and threat index, and completion time data as dependent variables. Effect sizes were calculated using partial eta squared (η_p^2). As the perceived support availability data was non-normally distributed, this data was subject to a Kruskal-Wallis test with follow-up Mann-Whitney U tests to examine differences between the four experimental conditions.

4.3 Results

4.3.1 Perceived Required Effort and Support Availability

The ANOVA on the perceived required effort data revealed a significant main effect for perceived required effort, $F(1, 119) = 68.89$, $p < .001$, $\eta_p^2 = .37$. Participants in the low required effort condition (i.e., LRE-SA and LRE-NSA) reported that the task would require less effort than those in the high required effort condition (i.e., HRE-SA and HRE-NSA). However, there was no significant main effect for perceived support availability, $F(1, 119) = 0.39$, $p = .533$, $\eta_p^2 = .00$, and no significant interaction effect, $F(1, 119) = 0.07$, $p = .789$, $\eta_p^2 = .00$. The perceived required effort data are presented in Table 4.1.

The Kruskal-Wallis test on the support availability data revealed a significant difference between the experimental conditions, $H(3) = 75.35$, $p < .001$. Participants in the support available condition (i.e., LRE-SA and HRE-SA) reported that they perceived there would be more support available during the task than those in the no support available condition (i.e., LRE-NSA and HRE-

NSA) (all *ps* < .001). The perceived support availability data are presented in Table 4.1.

4.3.2 Demand/Resource Evaluations

The ANOVA on the demand evaluation data indicated a significant main effect for perceived required effort, $F(1, 119) = 55.20$, $p < .001$, $\eta_p^2 = .32$. Participants in the low required effort condition evaluated the task as less demanding than those in the high required effort condition. However, there was no significant main effect for perceived support availability, $F(1, 119) = 0.68$, $p = .411$, $\eta_p^2 = .01$, and no significant interaction effect, $F(1, 119) = 0.08$, $p = .784$, $\eta_p^2 = .00$. The demand evaluation data are presented in Table 4.1.

The ANOVA on the resource evaluation data indicated a significant main effect for perceived required effort, $F(1, 119) = 10.86$, $p = .001$, $\eta_p^2 = .09$. Participants in the low required effort condition reported having greater resources than those in the high required effort condition. However, there was no significant main effect for perceived support availability, $F(1, 119) = 0.94$, $p = .335$, $\eta_p^2 = .01$, and no significant interaction effect, $F(1, 119) = 0.34$, $p = .562$, $\eta_p^2 = .00$. The resource evaluation data are presented in Table 4.1.

The ANOVA on the demand resource evaluation score data revealed a significant main effect for perceived required effort, $F(1, 119) = 64.62$, $p < .001$, $\eta_p^2 = .36$. Participants in the low required effort condition reported higher scores, reflecting greater challenge, than those in the high required effort condition. However, there was no significant main effect for perceived support availability, $F(1, 119) = 1.76$, $p = .187$, $\eta_p^2 = .02$, and no significant interaction effect, $F(1, 119) = 0.04$, $p = .834$, $\eta_p^2 = .00$. The demand resource evaluation score data are presented in Table 4.1.

4.3.3 Cardiovascular Responses

The dependent t-test on the heart rate reactivity data revealed that in the entire sample, heart rate increased significantly from baseline (M = 6.25 bpm; SD = 5.09), $t(114)$ = 13.16, $p < .001$, d = 2.47, confirming task engagement and enabling the subsequent examination of challenge and threat states. The ANOVA on the challenge and threat index data revealed a significant main effect for perceived required effort, $F(1, 114)$ = 11.93, p = .001, η_p^2 = .10. Participants in the low required effort condition exhibited larger challenge and threat index values, indicating greater challenge, than those in the high required effort condition. However, there was no significant main effect for perceived support availability, $F(1, 114)$ = 0.22, p = .638, η_p^2 = .00, and no significant interaction effect, $F(1, 114)$ = 0.28, p = .601, η_p^2 = .00. The challenge and threat index data are presented in Table 4.1.

4.3.4 Task Performance

The ANOVA on the completion time data indicated a significant main effect for perceived required effort, $F(1, 119)$ = 15.42, $p < .001$, η_p^2 = .12. Participants in the low required effort condition completed the task quicker than those in the high required effort condition. However, there was no significant main effect for perceived support availability, $F(1, 119)$ = 0.04, p = .850, η_p^2 = .00, and no significant interaction effect, $F(1, 119)$ = 0.14, p = .714, η_p^2 = .00. The completion time data are presented in Table 4.1.

4.4 Discussion

Despite the BPSM (Blascovich, 2008a) receiving increasing research interest in terms of the outcomes associated with challenge and threat states

(e.g., Turner et al., 2012), to date, limited research has explicitly examined the antecedents of challenge and threat states proposed by this model. Thus, the aim of the present study was to examine the influence of two proposed antecedents, perceived required effort and support availability on demand/resource evaluations, challenge and threat states, and subsequent motor performance.

Perceptions of required effort and support availability were successfully manipulated using task instructions adapted from previous research (e.g., Uchino & Garvey, 1997). Specifically, participants in the low required effort condition reported that the task would require less effort to complete than participants in the high required effort condition. Moreover, participants in the support available condition indicated that more support would be available to them during the task than participants in the no support available condition. Importantly, given the nature of the task and experimental environment, the other antecedents proposed by the BPSM (Blascovich, 2008a), including psychological and physical danger, familiarity, uncertainty, and skills, knowledge and abilities, should have been approximately equivalent across the experimental conditions. For instance, none of the participants had prior experience of laparoscopic surgery and so familiarity, uncertainty, and skills, knowledge, and abilities should have been comparable across the conditions. Furthermore, the surgical task and experimental environment were consistent for all participants and contained no elements of psychological or physical danger and so these factors should have been similar across the conditions.

Table 4.1 Mean (*SD*) self-report, cardiovascular, and performance data for the four experimental conditions.

	LRE - SA		LRE - NSA		HRE - SA		HRE - NSA	
	Mean	*SD*	Mean	*SD*	Mean	*SD*	Mean	*SD*
Required effort (1-7)	3.87	1.07	4.03	1.38	5.47	0.82	5.53	0.68
Support availability (1-7)	4.83	1.29	1.60	1.33	4.90	1.49	1.63	1.07
Evaluated demands (1-6)	3.50	1.01	3.30	1.21	4.80	0.92	4.70	0.79
Evaluated resources (1-6)	4.20	0.76	4.27	0.98	3.53	1.04	3.80	0.96
DRES (-5 to +5)	0.70	1.29	0.97	1.47	-1.27	1.28	-0.90	1.16
Challenge and threat index	0.42	1.34	0.40	1.59	-0.77	1.72	-0.47	1.72
Completion time (s)	54.41	26.22	51.88	18.04	70.56	19.79	71.36	32.65

Note: LRE = low required effort; HRE = high required effort; SA = support available; NSA = no support available; DRES = demand resource evaluation score.

Consistent with our hypotheses, there were significant main effects of perceived required effort on demand/resource evaluations, challenge and threat index, and performance. Participants in the low required effort condition evaluated the task as less demanding and reported having greater personal coping resources than those in the high required effort condition. Subsequently, low required effort was associated with evaluating the task as a more of a challenge (i.e., personal coping resources match or exceed task demands; Blascovich, 2008a), compared to high required effort. Consistent with the predictions of the BPSM, this divergence in demand/resource evaluations was accompanied by different cardiovascular responses. Indeed, while participants in the low required effort condition exhibited larger challenge and threat index values more reflective of a challenge state (i.e., relatively higher cardiac output and lower total peripheral resistance; Seery, 2011), those in the high required effort condition displayed smaller index values more indicative of a threat state (i.e., relatively lower cardiac output and higher total peripheral resistance; Seery, 2011). Finally, congruent with previous research (Blascovich et al., 2004; Gildea et al., 2007; Mendes et al., 2007; Seery et al., 2010; Turner et al., 2012; Turner et al., 2013; Vine et al., 2013), the different evaluations and cardiovascular responses were accompanied by varying levels of performance. More specifically, participants in the low required effort condition performed better (i.e., quicker completion time) than those in the high required effort condition.

Contrary to our hypotheses, perceptions of support availability appeared to have little impact on how participants evaluated, responded to, and performed the surgical task. Furthermore, there were no significant interaction effects between perceptions of required effort and support availability on any of

the variables. Although the limited impact of perceived available support may be surprising, it should be noted that previous research examining the effect of perceived social support on cardiovascular reactivity to stress has revealed mixed results (see O'Donovan & Hughes, 2008). There are several possible explanations for the null effects. First, the participants may have perceived the available support differently. While some may have viewed the support as an extra coping resource, leading to a challenge state, others may have believed that the support providers were going to evaluate their performance (i.e., social evaluation), increasing the evaluated demands of the task, resulting in a threat state (see Blascovich et al., 1999; O'Donovan & Hughes, 2008). Second, the nature of the task may have affected how the available support was perceived. The surgical task was an individual task that participants were instructed to perform both accurately and quickly. Thus, although participants recognised that support was available (as evidenced by the support availability data), this support may not have influenced their demand/resource evaluations and cardiovascular responses as the participants may have felt that they would not have the necessary time to utilise the available support and still perform the task efficiently.

The findings of the present study have some important implications. From a theoretical perspective, the findings support the BPSM (Blascovich, 2008a) as an explanatory model of performance variability under stress. Furthermore, while the findings support the inclusion of perceived required effort as an antecedent of demand/resource evaluations and challenge and threat states in the model, they raise questions about the inclusion of the availability of support. However, further research is encouraged to experimentally examine these and other antecedents proposed by the BPSM (e.g., psychological and

physical danger, familiarity, uncertainty, and skills, knowledge and abilities; Blascovich, 2008a). Indeed, such research is important as it will help establish the relative importance and influence of each determinant on demand/resource evaluations, challenge and threat states, and performance, contributing to the further development of the model. Moreover, this research will also help elucidate which factors should be targeted in interventions aimed at encouraging individuals to evaluate and respond to stressful tasks more adaptively, as a challenge rather than a threat. From an applied perspective, the findings of the present study and previous research suggest that a more resilient, challenge state can be fostered via simple pre-task instructions that reduce the evaluated demands of the task and increase the evaluated resources of the individual (e.g., Feinberg & Aiello, 2010). More specifically, the findings imply such alterations can be accomplished using instructions that help the individual perceive that the task requires little physical and mental effort to perform effectively.

The limitations of the present study highlight some avenues for future research. First, the present study employed a between-subjects design and did not include baseline performance trials. Although this makes it difficult to control for any inherent group differences, baseline trials are problematic when assessing challenge and threat states. Indeed, previous task exposure has been shown to dampen cardiovascular responses and influence future demand/resource evaluations (Kelsey et al., 1999; Quigley et al., 2002; Vine et al., 2013). Second, based on early conceptions of the BPSM (Blascovich & Mendes, 2000), perceived required effort was manipulated using instructions regarding task difficulty and length as well as instructions directly relating to physical and mental effort. Subsequently, it is difficult to identify which of these

instructions had the strongest influence on perceptions of required effort, an interesting issue that should be addressed in future research. Third, how the antecedents proposed by the BPSM impact demand/resource evaluations and challenge and threat states could have been influenced by intrapersonal differences in various dispositional traits (Blascovich, 2014). However, such dispositional traits (e.g., trait social anxiety; Shimizu et al., 2011) were not assessed in the present study but could be examined in future research. Indeed, the present study examined a simplified model of the influence of two possible antecedents on demand/resource evaluations, challenge and threat states, and motor performance. Future research should therefore examine a more complex model in which dispositional traits and the interplay between additional antecedents are taken into consideration. Finally, although the cardiovascular markers of challenge and threat were recorded in the present study, the neuroendocrine responses predicted to underpin changes in these measures were not (e.g., cortisol; see Seery, 2011). Thus, future research is encouraged to record the neuroendocrine responses accompanying challenge and threat states to test the predictions of the BPSM and help our understanding of how these states affect the cardiovascular system.

To conclude, the results demonstrate that perceptions of required effort can have a powerful influence on how individuals' evaluate, respond to, and perform a stressful task. Furthermore, the results suggest that perceptions regarding the availability of support may have a limited impact on individuals' stress responses, although this antecedent warrants further investigation and might benefit from being examined using different support manipulations and experimental tasks (e.g., co-operative task). Finally, the results highlight that the performance of a stressful and novel task can be facilitated by providing pre-

task instructions that elicit a challenge state. More specifically, the results imply that reducing perceptions relating to task difficulty and the physical and mental effort required to successfully complete a stressful task may be an important message to include in such instructions.

Chapter four demonstrated that perceptions of required effort had a significant impact on individuals' demand/resource evaluations, challenge and threat states, and subsequent task performance. Specifically, chapter four showed that if a stressful task is perceived as requiring little effort to perform effectively, this results in a challenge evaluation (i.e., resources outweigh demands), a challenge cardiovascular response (i.e., relatively higher cardiac output and lower total peripheral resistance), and superior task performance (i.e., quicker completion times). Furthermore, chapter four revealed that perceptions of support availability had little impact on individuals' demand/resource evaluations, challenge and threat states, and subsequent task performance, and there was no interaction between perceptions of required effort and support availability. In the next chapter, the results of this thesis are summarised. Additionally, chapter five will discuss the implications and limitations of this thesis as well as directions for future challenge and threat research.

CHAPTER 5: DISCUSSION

5.1 Summary of Findings

This thesis aimed to test the predictions of the BPSM (Blascovich, 2008a) to further our understanding of performance variability under pressure. Chapters two and three demonstrated that challenge and threat states had immediate effects on the performance of novice and experienced individuals during both laboratory-based motor tasks and real pressurised competition. Specifically, consistent with the BPSM's predictions, these chapters showed that a challenge state resulted in better performance than a threat state. Furthermore, chapters two and three demonstrated that challenge and threat states had divergent effects on emotional, attentional, and behavioural (i.e., movement and muscle activity) responses to pressurised tasks, with a challenge state leading to more favourable responses than a threat state. Specifically, chapter two showed that challenge and threat states influenced novel motor task performance at a predominately kinematic (i.e., behavioural) level, impacting the quality of task-related movements. However, in chapter three, none of the emotional, attentional, or behavioural variables mediated the relationship between challenge and threat states and the motor performance of experienced individuals. Finally, chapter four demonstrated that required effort is a powerful antecedent of challenge and threat states. In particular, chapter four showed that perceptions of low required effort led individuals to evaluate a pressurised task as more of a challenge, exhibit a cardiovascular response more indicative of a challenge state, and perform the task better than perceptions of high required effort. However, perceptions of support availability

had limited impact on these variables and there was no interaction effect between perceived required effort and support availability.

5.2 Significance of Findings

5.2.1 Performance Consequences

According to the BPSM, a challenge state leads to better task performance than a threat state in motivated performance situations (Blascovich, 2008a). To date, the majority of research that has offered support for this assumption has been correlational. That is, most studies have examined if challenge and threat states, assessed either by demand/resource evaluations or cardiovascular markers, predict future task performance (Drach-Zahavy & Erez, 2002; Feinberg & Aiello, 2010; Gildea et al., 2007; O'Connor et al., 2010; Seery et al., 2010; Tomaka et al., 1993; Turner et al., 2012, 2013; White, 2008; Williams & Cumming, 2012). For example, Blascovich and colleagues demonstrated that a challenge state in response to a sport-relevant speech was associated with superior performance, four to six months later, during the competitive season (Blascovich et al., 2004). While this research gives an indication of the relationship between challenge and threat states and performance, the correlational nature of these studies, as well as the time delay between the assessment of challenge and threat states and performance, limit the causal inferences that can be drawn. Thus, this thesis aimed to address these limitations and provide a more causal understanding of the challenge and threat-performance relationship.

Specifically, chapter three achieved this by examining challenge and threat states immediately before (~ 5-10 minutes) a real pressurised competition. A challenge state predicted better competitive performance than a

threat state. Furthermore, chapters two and three offered a more causal understanding of the challenge and threat-performance relationship using laboratory-based procedures that offered a high degree of internal control. In these chapters, challenge and threat states were experimentally manipulated and assessed immediately before (~ 2 minutes) novice and experienced individuals performed a motor task. In both chapters, challenge and threat states were successfully manipulated and the challenge groups outperformed the threat groups. This result was confirmed in chapter four using a different motor task (laparoscopic surgery). Specifically, challenge and threat states were experimentally induced via predicted antecedents: perceived required effort and support availability. Individuals in the low required effort (i.e., challenge) conditions performed the motor task more proficiently than those in the high required effort (i.e., threat) conditions.

Given the different research designs employed, the short time periods between the assessment of challenge and threat states and performance, and the robust findings across different samples and tasks, this thesis extends previous research and provides strong evidence that challenge and threat states have divergent effects on performance. Thus, this thesis supports the link the BPSM makes between challenge and threat states and performance (Blascovich, 2008a), although not all iterations of the BPSM have explicitly made this link (e.g., Blascovich & Mendes, 2000; Seery, 2011). The findings of this thesis therefore suggest that future iterations of the BPSM should consider including the assumption that a challenge state often leads to better performance than a threat state. Furthermore, this thesis is the first to show that challenge and threat states can have immediate effects on the performance of motor tasks. Indeed, previous research that examined the direct effects of

challenge and threat states on performance focused on cognitive tasks (e.g., Tomaka et al., 1993; Turner et al., 2012). Thus, the findings of this thesis also support the predictions of the TCTSA (Jones et al., 2009), a recent theory that applied the core assumptions of the BPSM to sport.

5.2.2 Underlying Mechanisms

Despite growing research into the effects of challenge and threat states on performance, limited research has examined how these states influence emotions, attention, and behaviour. This thesis aimed to be the first to shed light on this issue. First, according to the TCTSA, a challenge state should lead to more favourable emotional responses than a threat state, with a challenge state resulting in less negative emotions and more facilitative interpretations of emotions compared to a threat state (Jones et al., 2009). While recent correlational studies have offered limited support for this prediction (Meijen et al., 2013a, 2013b; Turner et al., 2012, 2013), experimental studies have offered stronger support (Quested et al., 2011; Williams & Cummings, 2012). The findings of chapters two and three add substantial strength to this research and further support the TCTSA. Indeed, in both chapters, the challenge groups reported experiencing less cognitive and somatic anxiety as well as more facilitative interpretations of cognitive and somatic anxiety symptoms than the threat groups. These positive findings might be attributable to the use of an expedient measure of anxiety symptoms (IAMS; Thomas et al., 2002), rather than a more lengthy measure of various emotions (Sport Emotion Questionnaire; Jones, Lane, Bray, Uphill, & Catlin, 2005).

Second, challenge and threat states have been suggested to have different effects on attention (Blascovich et al., 2004). Specifically, according to

the TCTSA, attention is directed towards task-relevant cues in a challenge state but towards task-irrelevant cues, or controlling one's actions, in a threat state (Jones et al., 2009). Thus, a challenge state is predicted to result in more optimal attention than a threat state. However, no research had examined this proposition. This thesis therefore represents the first empirical support for this prediction. Indeed, chapters two and three demonstrated that the challenge groups displayed longer quiet eye durations than the threat groups. Importantly, the quiet eye has been well established as a marker of optimal visual attention and longer quiet eye durations have been shown to underpin higher levels of expertise and proficiency in numerous motor tasks (Mann et al., 2007; Wilson, 2012). Furthermore, in chapter three, the challenge group also reported less conscious processing than the threat group. Crucially, research has demonstrated that directing less attention towards movements during the execution of autonomous motor skills leads to better performance in pressurised tasks (Masters & Maxwell, 2008; Wulf, 2013).

Third, challenge and threat states are predicted to result in different behaviours and movements (Blascovich, 2014; Jones et al., 2009). To date, limited research has supported this proposition (O'Connor et al., 2010; Weisbuch et al., 2009). For example, Mendes and colleagues found that a challenge state resulted in less freezing and avoidance posture as well as more smiling during an interaction task compared to a threat state (Mendes et al., 2007). This thesis adds some support to this prediction. Indeed, in chapter two, a challenge state resulted in more effective task-related movement patterns (i.e., lower clubhead acceleration and jerk) than a threat state. Although no differences were found in chapter three, it is suggested that this was because either the control of the putting stroke has less influence on the proficiency of

experienced golfers (Cooke et al., 2011), or because some important movement-related variables were not assessed (e.g., clubhead alignment; Karlsen et al., 2008). Moreover, a challenge state is said to lead to less muscular activation than a threat state (Wright & Kirby, 2003). This thesis provided the first empirical test of this assumption and offered mixed support. Indeed, in chapter two, a challenge state resulted in lower activation of the extensor carpi radialis muscle than a threat state during the performance of the motor task. While no differences were found in chapter three, it is argued that this was because muscle activity patterns may have less impact on experienced golfers' putting performance compared to novices (Cooke et al., 2010, 2011).

In summary, the above findings support the predictions of various authors and theories and suggest that challenge and threat states can have divergent effects on individuals' emotional, attentional, and behavioural responses during pressurised situations, with a challenge state resulting in more favourable responses than a threat state. To further explore if these differences could explain why the challenge groups outperformed the threat groups, mediation analyses were conducted in chapters two and three. Subsequently, this thesis represents one of the first explorations into the underlying mechanisms through which challenge and threat states operate. The findings revealed limited support for emotional and attentional mechanisms. However, in chapter two, mediation analyses revealed that challenge and threat states impacted novel motor performance via behavioural mechanisms, with a challenge state leading to more effective task-related movements than a threat state. Unfortunately, this finding was not corroborated in chapter three. The lack of mediation effects may be primarily due to the cross-sectional designs employed in this thesis. Indeed, authors have suggested that longitudinal

designs in which potential mechanisms are modelled over time might offer a more sensitive investigation of probable mechanisms (Uchino et al., 2012). It is hoped that in combination with future research, these results will aid the expansion and refinement of the BPSM and other theories (e.g., TCTSA) so that they include specific predictions regarding the mechanisms through which challenge and threat states operate.

5.2.3 Antecedents

According to the BPSM (Blascovich, 2008a), a range of interrelated factors can influence individuals' demand and resource evaluations and ultimately whether individuals exhibit a challenge or threat state in response to a pressurised situation. These antecedents include psychological and physical danger, familiarity, uncertainty, required effort, skills, knowledge and abilities, and the availability of support (Blascovich, 2008a). Despite some antecedents emerging from research using the cardiovascular markers of challenge and threat states to examine psychological theories relating to intra-individual processes (e.g., social power; Scheepers et al., 2012), no research has explicitly examined the antecedents proposed by the BPSM. Thus, this thesis represents seminal work in this area and examined two of these antecedents: perceived required effort and support availability. Specifically, chapter four revealed that perceptions of low required effort led to a task being evaluated as more of a challenge, a challenge cardiovascular response, and better motor performance than perceptions of high required effort. However, perceptions of support availability had limited impact on demand/resource evaluations, challenge and threat states, and motor performance. Furthermore, perceptions

of required effort and support availability did not interact with one another to influence these variables.

While no specific predictions were made regarding interaction effects, the null effects of perceived support availability were surprising. However, two possible explanations exist for the limited influence of perceived support availability. First, the support may have been interpreted differently. Although some individuals may have viewed the support as an extra coping resource, resulting in a challenge state, others might have felt the support provider was going to evaluate their performance (i.e., social evaluation), making the task seem more demanding, causing a threat state (Kelsey et al., 2000; O'Donovan & Hughes, 2008). Indeed, Blascovich and colleagues found that individuals who performed an unlearned task in the presence of others displayed a threat cardiovascular response (Blascovich et al., 1999). Second, the nature of the task may have played an important role. Indeed, the surgical task was an independent task that individuals were asked to complete as quickly and accurately as possible. Thus, while individuals recognised that support was available, this may not have impacted upon their demand/resource evaluations and cardiovascular responses as they may have felt that they lacked the necessary time to utilise the support available to them and still perform the task proficiently.

In summary, the findings of this thesis support the inclusion of required effort as an antecedent in the BPSM but raise questions about the inclusion of support availability. It is hoped that the findings of this thesis will spark further investigation into the antecedents of challenge and threat states proposed by the BPSM. Indeed, such research will not only aid future developments of the

BPSM but will also help identify what factors are most crucial to focus upon in interventions aimed at promoting a challenge state in response to pressurised situations. Furthermore, the development of these interventions would also benefit from more research into the antecedents of challenge and threat states proposed by other theories. For example, the TCTSA predicts that self-efficacy, perceptions of control, and achievement goals determine challenge and threat states via their influence on resource evaluations (Jones et al., 2009). Specifically, the TCTSA suggests that high self-efficacy, high perceived control, and a focus on approach goals promote higher resource evaluations and a challenge state. Conversely, the TCTSA argues that low self-efficacy, low perceived control, and a focus on avoidance goals induce lower resource evaluations and a threat state (Jones et al., 2009).

5.3 Implications of Findings

The findings of this thesis have some important implications. From a theoretical perspective, as noted above, the findings of all chapters support the predictions of the BPSM (Blascovich, 2008a) and highlight the model as a useful framework that helps explain why individuals respond and perform differently under pressure. Furthermore, the findings suggest that challenge and threat states can be assessed both subjectively, via self-report measures of situational demands and personal coping resources, and objectively via changes in cardiovascular markers including cardiac output and total peripheral resistance. Indeed, although authors have often criticised the use of self-report measures of challenge and threat states due to problems such as biases (e.g., social desirability bias; Blascovich, 2008a; Seery, 2011, 2013), the consistent findings across both self-report and objective measures in this thesis suggest

that such subjective measures may represent an expedient alternative. Indeed, this is important as it is often not logistical to fit individuals with an impedance cardiograph device in order to measure cardiovascular markers of challenge and threat states before real pressurised situations (e.g., an exam, job interview, or sporting competition). Moreover, these markers cannot often be accurately recorded during such situations (particularly sporting competition) due to concerns regarding movement artefacts.

The findings of this thesis also have some interesting applied implications. First, in combination with previous studies that have demonstrated that a challenge state predicts superior task performance than a threat state (Blascovich et al., 2004; Gildea et al., 2007; Seery et al., 2010; Turner et al., 2012, 2013; Vine et al., 2013), the findings of chapter three (study 1) with experienced individuals has implications for screening and individual selection. Specifically, although provocative, the findings imply that selectors (e.g., interviewers, coaches) may want to only select individuals who respond to a pressurised situation with a challenge state and avoid selecting individuals who respond to a pressurised situation with a threat state. Indeed, the findings of this thesis suggest that selectors could use both subjective (e.g., cognitive appraisal ratio) and objective (e.g., cardiovascular responses) tools to screen for such resilient and non-resilient individuals and assess their readiness to perform under pressure. Such selection may ultimately lead to improved performance outcomes and is likely to be particularly important in safety-critical industries (e.g., surgery, police, aviation, and military). For example, aviation companies could ask pilots' to complete the cognitive appraisal ratio and record participants cardiovascular responses prior to difficult flights in order to screen pilots' readiness to fly. By only allowing those pilots reporting and displaying a

challenge state to fly, aviation companies may ultimately improve passenger satisfaction and safety. However, it is important to note that such screening should not be conducted in isolation and that other factors should also be taken into consideration (e.g., physical attributes).

Second, and perhaps more productively, the findings of chapters two and three (study 2) suggest that interventions aimed at encouraging individuals to evaluate pressurised situations more adaptively, as a challenge rather than a threat, should facilitate stress-resilient performance. In order to accomplish this, such interventions need to reduce the evaluated demands of the situation and/or increase the evaluated coping resources of the individual. One particular intervention that has received support in the literature and might achieve this, is training with anxiety (Oudejans & Pijpers, 2009, 2010). For example, Nieuwenhuys and Oudejans (2011) found that police officers who were trained on a shooting task with anxiety (i.e., while being shot at by an opponent) displayed greater shooting accuracy in a subsequent pressure test than officers who were trained without anxiety. Thus, training with anxiety may lead to future pressurised situations being evaluated as less demanding and/or the individual evaluating that they have sufficient coping resources, due to the previous stressful situations they have encountered. While future research is needed to examine this intervention, research has shown that other interventions including imagery (e.g., Williams et al., 2010) and reappraisal (e.g., Jamieson, Nock, & Mendes, 2012) can promote a challenge state prior to a pressurised situation. For instance, Jamieson and colleagues found that students who were given a reappraisal intervention (i.e., informed that arousal during stressful situations aids performance) displayed greater sympathetic activation (i.e., a challenge

state) and performed better on subsequent math exams than students in a control group (Jamieson, Mendes, Blackstock, & Schmader, 2010).

Third, in conjunction with previous research that has successfully manipulated challenge and threat states (e.g., Feinberg & Aiello, 2010; Tomaka et al., 1997); the findings of all chapters in this thesis demonstrate that an intervention as subtle and inexpensive as manipulating the way a pressurised situation is framed can foster a challenge state. Indeed, chapters two and three (study 2) showed that general instructions that deemphasise the difficulty of the task and encourage individuals to view the task as a challenge to be met and overcome can be employed to promote a challenge state. Such instructions could be included in discussions between coaches and athletes prior to important sporting competitions, or between senior and novice surgeons before difficult surgical procedures, in order to produce better performance outcomes. Moreover, chapter four demonstrated that instructions that focus on perceptions of required effort might be particularly effective. Specifically, chapter four showed that informing an individual that a task will not be difficult and will require little physical and mental effort to perform effectively appears to induce a challenge state. Collectively, the findings of this thesis suggest that coaches, managers, and leaders should be mindful of the impact their instructions can have on individuals' performance and that these individuals should aim to frame pressurised situations in a manner consistent with a challenge state.

5.4 Limitations of Research

Despite the novel findings, the research within this thesis is not without its limitations. First, the adoption of between-subjects designs and the absence of baseline trials in all chapters may be viewed as potential limitations. Although

this makes it difficult to control for any inherent between-group differences that may still be present after randomisation, baseline trials can be problematic when assessing challenge and threat states. Indeed, previous research has shown that the amount of exposure to a task dampens cardiovascular responses. For example, Kelsey and colleagues found that groups who performed a stressful mental arithmetic task after performing the task previously, displayed attenuated cardiovascular reactivity compared to groups who only performed the stressful task after a prolonged rest (Kelsey et al., 1999). Furthermore, research has demonstrated that prior task performance can have a significant impact on future demand/resource evaluations (Rith-Najarian, McLaughlin, Sheridan, & Nock, 2014). For instance, Quigley and colleagues found that participants who made more correct responses during a mental arithmetic task were more likely to make challenge evaluations following the task (Quigley et al., 2002). Given these issues it is unsurprising that much of the challenge and threat research has utilised between-subjects designs rather than within-subject designs (e.g., Feinberg & Aiello, 2010).

Second, the limited number of trials used to assess motor performance in all chapters could be seen as a potential limitation. While using a larger number of trials helps improve measurement reliability, a large number of trials also opens up the possibility that performance may be influenced by re-evaluation. Indeed, various authors have noted that demand and resource evaluations (and thus challenge and threat states) are dynamic and fluctuate throughout the performance of a task as new information becomes available (Blascovich, 2008a; Seery, 2011). Thus, while individuals might evaluate a task as a threat at first, this might change after a few trials, causing individuals to re-evaluate the task as less threatening or even challenging, and vice versa. Research has

supported the assertion that demand/resource evaluations are dynamic. For example, Quigley and colleagues observed that women who initially evaluated a mental arithmetic task as a threat re-evaluated the task as a challenge once they had performed the task successfully (Quigley et al., 2002). The present research therefore employed sufficient trials to ensure good measurement reliability (as Cooke et al., 2010; Cooke et al., 2011), but a limited number of trials to reduce the likelihood and influence of re-evaluation on task performance.

Third, the fact that cardiovascular data was recorded before rather than during the tasks performed in the motivated performance situations in this thesis may be seen as a potential limitation. Indeed, the majority of previous research has recorded the cardiovascular markers of challenge and threat during tasks including speech and mental arithmetic tasks (e.g., Blascovich et al., 2004; Tomaka et al., 1997). However, this approach was adopted in this thesis due to concerns regarding movement artefacts (Blascovich & Mendes, 2000). Specifically, it was feared that the physical movements performed during the tasks (standing up, moving arms etc.) might complicate individuals' cardiovascular reactivity and mask the responses that differentiate challenge and threat states, making the cardiovascular data harder to analyse and interpret as well as less accurate and possibly unusable (Blascovich et al., 2004). Thus, it was decided that cardiovascular data would be recorded during the time immediately before each task when participants were reflecting on the instructions they had received and thinking about the upcoming tasks.

Finally, while the cardiovascular markers of challenge and threat were recorded in all chapters, the neuroendocrine responses proposed by the BPSM

to underpin any changes in these markers were not. A challenge state is said to result in relatively higher cardiac output and lower total peripheral resistance compared to a threat state due to differences in neurological activation. Specifically, while only sympathetic-adrenomedullary activation occurs during a challenge state, pituitary-adrenocortical activation also occurs during a threat state (Blascovich, 2008a; Seery, 2011). Given that greater pituitary-adrenocortical activation is marked by increases in the hormone cortisol, a threat state should therefore be associated with higher cortisol levels than a challenge state. Although research has shown that a threat evaluation is associated with heightened cortisol (e.g., Harvey, Nathens, Bandiera, & LeBlanc, 2010), to date, no research has examined the relationship between the cardiovascular markers of challenge and threat and hormones such as cortisol. This may be due to the complexities inherent in measuring cortisol and other hormones such as catecholamines via blood, saliva, and urine sampling methods (Dickerson & Kemeny, 2004). For example, there is a 20-40 minute delay in detecting elevations in cortisol that result from stressful tasks. It was because of these methodological issues that the neuroendocrine responses were not assessed in this thesis.

5.5 Future Research Directions

The findings of this thesis highlight potential avenues for future research. First, as mentioned above, despite an abundance of research validating the cardiovascular indices of challenge and threat states, no research has examined the BPSM's proposition that challenge and threat cardiovascular patterns are driven by different neuroendocrine responses (Blascovich, 2008a; Seery, 2011). Thus, a potentially interesting avenue for future research would

be to examine the neuroendocrine responses that accompany challenge and threat states by assessing hormonal responses (e.g., catecholamines and cortisol) before, during, and after a pressurised motivated performance situation using various sampling techniques (Dickerson & Kemeny, 2004). Such research would advance the BPSM and help elucidate precisely how challenge and threat evaluations impact the cardiovascular system. Furthermore, the greater cardiac activity and vasodilation of blood vessels during a challenge state is predicted to lead to increased blood flow to the brain and muscles, resulting in more glucose and free fatty acids being available to fuel energy production (Dienstbier, 1989). To date, no research has examined this prediction; however, future research could investigate whether a challenge state is associated with greater oxygenated blood flow by using technology such as near-infrared spectroscopy (Scheeren, Schober, & Schwarte, 2012).

Second, although this thesis demonstrates that challenge and threat states can have an immediate effect on motor task performance, these tasks have been limited to aiming tasks. Therefore, a potential avenue for future research is to explore if a challenge state results in better performance than a threat state across a range of different motor tasks including decision-making, team-based, and anaerobic power tasks (Jones et al., 2009). Indeed, further research into the impact of these states on decision-making performance may be particularly interesting given the mixed findings to date. For example, although Turner and colleagues (2012) found that a challenge state was associated with superior decision-making performance in a cognitive task, De Wit and colleagues (2012) found that a threat state was related to better performance. Furthermore, while increased cortisol (i.e., a threat state) has been associated with poorer performance in normal decision-making tasks

(Starke, Wolf, Markowitsch, & Brand, 2008), it has also been related to better performance in threat-related decision-making tasks (e.g., police shooting; Akinola & Mendes, 2012). Thus, future research could examine the immediate effects of challenge and threat states on the performance of motor tasks that require both normal (e.g., badminton serve anticipation) and threat-related (e.g., karate combat situations) decision-making.

Finally, chapter four is the first study to explicitly examine if any of the antecedents proposed by the BPSM interact and influence demand/resource evaluations, challenge and threat states, and motor performance. Thus, a possible avenue for future research would be to explore the interplay between the other antecedents and how these influence challenge and threat states and task performance. For example, researchers could manipulate perceptions of psychological danger via anticipation of electric shock (i.e., high danger vs. low danger) and ability using performance on a comparable motor task (i.e., high ability vs. low ability). Moreover, how the antecedents proposed by the BPSM impact challenge and threat states could be influenced by intrapersonal differences in various dispositional traits (Blascovich, 2014). For instance, high levels of trait social anxiety have been associated with a threat state during motivated performance situations (Shimizu et al., 2011). Future research could therefore examine a more complex model and investigate how dispositional traits interact with the antecedents proposed by the BPSM to influence challenge and threat states.

5.6 Conclusion

This thesis makes a significant contribution to the challenge and threat literature and offers considerable support for the BPSM as an explanatory

model of performance variability under pressure. This thesis is the first to show that challenge and threat states can have an immediate effect on the performance of both laboratory-based motor tasks and real pressurised competition. Specifically, it demonstrates that a challenge state results in superior performance than a threat state, suggesting that interventions aimed at promoting a challenge state should help facilitate better performance in pressurised contexts. Indeed, it indicates that an intervention as simple as manipulating the verbal instructions an individual receives before a pressurised situation could induce a challenge state. Second, this thesis is among the first to investigate the potential mechanisms through which challenge and threat states influence motor performance. Specifically, it demonstrates that challenge and threat states result in divergent emotional, attentional, and behavioural (i.e., movement and muscle activity) responses under pressure, with a challenge state leading to more favourable responses. Mediation analyses confirmed that challenge and threat states influenced novel motor task performance at a predominantly kinematic (i.e., behavioural) level, impacting the quality of task-related movements. Finally, this thesis is the first to explicitly examine any of the antecedents of challenge and threat states proposed by the BPSM. Indeed, it demonstrates that perceptions of required effort have a more powerful influence on demand/resource evaluations, challenge and threat states, and motor performance than perceptions of support availability. Specifically, perceptions of low required effort led to a task being evaluated as more of a challenge, a cardiovascular response more indicative of a challenge state, and better performance than perceptions of high required effort. In summary, this thesis has significantly advanced our understanding of how pressure can influence the

performance of motor tasks and how favourable responses to pressure can be facilitated to ensure stress-resilient performance.

CHAPTER 6: REFERENCES

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Appendix 1. Additional Published Manuscripts and Conference Presentations

Articles

Vine, S.J., Uiga, L., Lavric, A., **Moore, L.J.**, & Wilson, M.R. (under review). Individual reactions to stress predict performance during a critical aviation incident. *Anxiety, Stress, and Coping.*

Vine, S.J., **Moore, L.J.**, Cooke, A., Ring, C., & Wilson, M.R. (2013). Quiet eye training: A means to implicit motor learning. *International Journal of Sport Psychology*, *44*, 367-386.

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Appendix 2. Challenge and Threat Manipulation Instructions (Novice)

Challenge Instructions

The rest period has now finished. We will shortly ask you to perform a golf putting task consisting of six putts from a distance of eight feet to a half-size hole. This is the most important part of the experiment and it is very important that you try, ideally, to get the ball in the hole or finish the ball as close to the hole as you possibly can with each putt. We will instruct you when you may begin each putt, and then you can hit each putt in your own time. After each putt, we will record the distance the ball finishes from the hole. Do you have any questions?

The average distance from the hole will be calculated for each participant and placed on a leader board. At the end of the study the leader board will be emailed to all participants, their respective golf course, and displayed on a noticeboard. The top five performers will be awarded cash prizes of £50, £25, £20, £15, and £10, respectively, whilst the worst five performers will be interviewed at length about their poor performance. Finally, please note that each putt will be recorded on a digital video camera and maybe used to aid teaching and presentations in the future.

Try and think of the upcoming golf putting task as a challenge to be met and overcome. Think of yourself as someone capable of meeting that challenge. We think that you are more than capable of meeting the challenges of this task. Our research has shown that most golfers with your experience are able to handle the task you are about to complete. Although some golfers have expected the task to be difficult given the half-size hole, even golfers with a higher handicap and less golf putting experience than yourself found that they

were more than able to perform well on the task and felt very good about their performance. Again, although this task may appear difficult, remind yourself that you are capable of performing well and try your best.

With these instructions in mind, please now sit quietly for 1 minute and think about the upcoming task.

Threat Instructions

The rest period has now finished. We will shortly ask you to perform a golf putting task consisting of six putts from a distance of eight feet to a half-size hole. This is the most important part of the experiment and it is very important that you try, ideally, to get the ball in the hole or finish the ball as close to the hole as you possibly can with each putt. We will instruct you when you may begin each putt, and then you can hit each putt in your own time. After each putt, we will record the distance the ball finishes from the hole. Do you have any questions?

The average distance from the hole will be calculated for each participant and placed on a leader board. At the end of the study the leader board will be emailed to all participants, to their respective golf course, and displayed on a noticeboard. The top five performers will be awarded cash prizes of £50, £25, £20, £15, and £10, respectively, whilst the worst five performers will be interviewed at length about their poor performance. Finally, please note that each putt will be recorded on a digital video camera and maybe used to aid teaching and presentations in the future.

Given the half-size hole, the upcoming golf putting task can be difficult and frustrating, and is a task that you may not perform to a high standard. We

think that you might struggle to meet the demands of the task and perform well. Our research has shown that most participants with your level of experience are unable to perform well on the task you are about to complete. Although some golfers have expected the task to be easy, even elite golfers with single-figure handicaps and greater golf putting experience than you found that they were unable to perform well on the difficult task and felt very unhappy about their performance. Again, although you may find this task difficult, do try your best.

With these instructions in mind, please now sit quietly for 1 minute and think about the upcoming task.

Appendix 3. Challenge and Threat Manipulation Instructions (Experienced)

Challenge Instructions

The rest period has now finished. We will shortly ask you to perform a golf putting task consisting of six putts from a distance of eight feet to a half-size hole. This is the most important part of the experiment and it is very important that you try, ideally, to get the ball in the hole or finish the ball as close to the hole as you possibly can with each putt. We will instruct you when you may begin each putt, and then you can hit each putt in your own time. After each putt, we will record the distance the ball finishes from the hole. Do you have any questions?

The average distance from the hole will be calculated for each participant and placed on a leader board. At the end of the study the leader board will be emailed to all participants, their respective golf course, and displayed on a noticeboard. The top five performers will be awarded cash prizes of £50, £25, £20, £15, and £10, respectively, whilst the worst five performers will be interviewed at length about their poor performance. Finally, please note that each putt will be recorded on a digital video camera and maybe used to aid teaching and presentations in the future.

Try and think of the upcoming golf putting task as a challenge to be met and overcome. Think of yourself as someone capable of meeting that challenge. We think that you are more than capable of meeting the challenges of this task. Our research has shown that most golfers with your experience are able to handle the task you are about to complete. Although some golfers have expected the task to be difficult given the half-size hole, even golfers with a higher handicap and less golf putting experience than yourself found that they

were more than able to perform well on the task and felt very good about their performance. Again, although this task may appear difficult, remind yourself that you are capable of performing well and try your best.

With these instructions in mind, please now sit quietly for 1 minute and think about the upcoming task.

Threat Instructions

The rest period has now finished. We will shortly ask you to perform a golf putting task consisting of six putts from a distance of eight feet to a half-size hole. This is the most important part of the experiment and it is very important that you try, ideally, to get the ball in the hole or finish the ball as close to the hole as you possibly can with each putt. We will instruct you when you may begin each putt, and then you can hit each putt in your own time. After each putt, we will record the distance the ball finishes from the hole. Do you have any questions?

The average distance from the hole will be calculated for each participant and placed on a leader board. At the end of the study the leader board will be emailed to all participants, to their respective golf course, and displayed on a noticeboard. The top five performers will be awarded cash prizes of £50, £25, £20, £15, and £10, respectively, whilst the worst five performers will be interviewed at length about their poor performance. Finally, please note that each putt will be recorded on a digital video camera and maybe used to aid teaching and presentations in the future.

Given the half-size hole, the upcoming golf putting task can be difficult and frustrating, and is a task that you may not perform to a high standard. We

think that you might struggle to meet the demands of the task and perform well. Our research has shown that most participants with your level of experience are unable to perform well on the task you are about to complete. Although some golfers have expected the task to be easy, even elite golfers with single-figure handicaps and greater golf putting experience than you found that they were unable to perform well on the difficult task and felt very unhappy about their performance. Again, although you may find this task difficult, do try your best.

With these instructions in mind, please now sit quietly for 1 minute and think about the upcoming task.

Appendix 4. Required Effort and Support Availability Manipulation Instructions

Low Required Effort and Support Available Instructions

The rest period has now finished. We will shortly ask you to perform a laparoscopic surgery task consisting of one trial on a ball pick-and-drop task. This is the most important part of the experiment and it is very important that you try, ideally, to complete the task as quickly as you can with as few errors as possible. We will instruct you when you may begin the trial, and then you should complete the trial as quickly and accurately as possible. After the trial, we will record the completion time and the number of errors. That is the time it takes you to finish the task and the number of balls you knock off or drop. Do you have any questions?

A measure of task performance will be calculated for each participant and placed on a leader board. At the end of the study the leader board will be emailed to all participants and displayed on a noticeboard so you can compare how you did against other students. The top five performers will be awarded cash prizes of £50, £25, £20, £15, and £10, respectively. The worst five performers will be interviewed. Further, please note that the trial will be recorded on a digital video camera and maybe used to aid teaching and presentations in the future.

The simple task you are about to complete is designed to help identify medical students who have good basic laparoscopic surgery skills. The task is straightforward. It requires very little physical and mental effort to perform effectively and will only take approximately 60 seconds to complete. We will be right next to you while you perform the task. If you require assistance for any reason, or if you have any questions regarding the task, please don't hesitate to

ask one of us. We appreciate your participation in the experiment, and we'd like to assist you should you need any help.

With these instructions in mind, please now sit quietly for 1 minute and think about the upcoming task.

Low Required Effort and No Support Available Instructions

The rest period has now finished. We will shortly ask you to perform a laparoscopic surgery task consisting of one trial on a ball pick-and-drop task. This is the most important part of the experiment and it is very important that you try, ideally, to complete the task as quickly as you can with as few errors as possible. We will instruct you when you may begin the trial, and then you should complete the trial as quickly and accurately as possible. After the trial, we will record the completion time and the number of errors. That is the time it takes you to finish the task and the number of balls you knock off or drop. Do you have any questions?

A measure of task performance will be calculated for each participant and placed on a leader board. At the end of the study the leader board will be emailed to all participants and displayed on a noticeboard so you can compare how you did against other students. The top five performers will be awarded cash prizes of £50, £25, £20, £15, and £10, respectively. The worst five performers will be interviewed. Further, please note that the trial will be recorded on a digital video camera and maybe used to aid teaching and presentations in the future.

The simple task you are about to complete is designed to help identify medical students who have good basic laparoscopic surgery skills. The task is

straightforward. It requires very little physical and mental effort to perform effectively and will only take approximately 60 seconds to complete. We will be in the room while you perform the task. However, if you require any assistance or have any questions regarding the task, you will not be able to ask one of us. Although we appreciate your participation in the experiment, we cannot assist you should you need any help.

With these instructions in mind, please now sit quietly for 1 minute and think about the upcoming task.

High Required Effort and Support Available Instructions

The rest period has now finished. We will shortly ask you to perform a laparoscopic surgery task consisting of one trial on a ball pick-and-drop task. This is the most important part of the experiment and it is very important that you try, ideally, to complete the task as quickly as you can with as few errors as possible. We will instruct you when you may begin the trial, and then you should complete the trial as quickly and accurately as possible. After the trial, we will record the completion time and the number of errors. That is the time it takes you to finish the task and the number of balls you knock off or drop. Do you have any questions?

A measure of task performance will be calculated for each participant and placed on a leader board. At the end of the study the leader board will be emailed to all participants and displayed on a noticeboard so you can compare how you did against other students. The top five performers will be awarded cash prizes of £50, £25, £20, £15, and £10, respectively. The worst five performers will be interviewed. Further, please note that the trial will be

recorded on a digital video camera and maybe used to aid teaching and presentations in the future.

The difficult task you are about to complete is designed to help identify medical students who have good basic laparoscopic surgery skills. The task is tough. It requires a great deal of physical and mental effort to perform effectively and will take approximately 60 seconds to complete. We will be right next to you while you perform the task. If you require assistance for any reason, or if you have any questions regarding the task, please don't hesitate to ask one of us. We appreciate your participation in this experiment, and we'd like to assist you should you need any help.

With these instructions in mind, please now sit quietly for 1 minute and think about the upcoming task.

High Required Effort and No Support Available Instructions

The rest period has now finished. We will shortly ask you to perform a laparoscopic surgery task consisting of one trial on a ball pick-and-drop task. This is the most important part of the experiment and it is very important that you try, ideally, to complete the task as quickly as you can with as few errors as possible. We will instruct you when you may begin the trial, and then you should complete the trial as quickly and accurately as possible. After the trial, we will record the completion time and the number of errors. That is the time it takes you to finish the task and the number of balls you knock off or drop. Do you have any questions?

A measure of task performance will be calculated for each participant and placed on a leader board. At the end of the study the leader board will be

emailed to all participants and displayed on a noticeboard so you can compare how you did against other students. The top five performers will be awarded cash prizes of £50, £25, £20, £15, and £10, respectively. The worst five performers will be interviewed. Further, please note that the trial will be recorded on a digital video camera and maybe used to aid teaching and presentations in the future.

The difficult task you are about to complete is designed to help identify medical students who have good basic laparoscopic surgery skills. The task is tough. It requires a great deal of physical and mental effort to perform effectively and will take approximately 60 seconds to complete. We will be in the room while you perform the task. However, if you require any assistance or have any questions regarding the task, you will not be able to ask one of us. Although we appreciate your participation in the experiment, we cannot assist you should you need any help.

With these instructions in mind, please now sit quietly for 1 minute and think about the upcoming task.