THE CONTRIBUTION OF COPING RELATED VARIABLES AND CARDIAC VAGAL ACTIVITY ON PERFORMANCE UNDER PRESSURE

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ABSTRACT

Successful performance under pressure requires effective psychophysiological self-regulation. It is suggested that activity in the parasympathetic nervous system, termed cardiac vagal activity, is a marker of self-regulation as theorised by the neurovisceral integration model (Thayer et al. 2009). This psychophysiological marker has been shown to be sensitive to pressure and help facilitate performance in pressurised situations.

Research examining cardiac vagal activity has started to incorporate subjective coping related variables (trait emotional intelligence, reinvestment, cognitive appraisal, attention) in a combined approach. This approach develops a holistic understanding of the psychophysiological reactions that occur under pressure and ultimately how this influences performance. As a result, this research has two main aims. Firstly, to understand the contribution of coping related variables on cardiac vagal activity throughout a pressurised task. Secondly, to understand the contribution of coping related variables and cardiac vagal activity on performance under pressure.

This thesis employed an experimental approach whereby three empirical studies were conducted. The first examined coping related variables and cardiac vagal activity in cognitive performance. Athletes (n=49) realized a working memory task under low and high pressure conditions. Findings demonstrated that individuals who had higher cardiac vagal activity at rest were more likely to have higher cardiac vagal activity throughout the pressurised task. Cardiac vagal recovery from pressure was negatively affected by the likelihood to think back to past decisions, through the trait of decision reinvestment under high pressure. Performance was predicted by task cardiac vagal activity in the high pressure condition only.

The second study examined the same variables in a psychomotor task. Athletes (n=51) competed in a dart throwing task in high and low pressure conditions. As in study one, individuals who had higher cardiac vagal activity at rest were more likely to have higher cardiac vagal activity throughout the pressurised task. Performance was predicted by attention in the high pressure condition only, suggesting attentional resources were placed under more demand in the high pressure condition. Unlike in study one, cardiac vagal activity did not play a role in the prediction of performance. This demonstrated that tasks that are not solely based on executive functioning may not benefit from higher levels of cardiac vagal activity.

The third and final study examined the same variables in 38 prone rifle shooting athletes, during a simulated rifle competition under both high and low pressure. Task cardiac vagal activity was predicted by trait emotional intelligence self-control in both low and high pressure conditions, further supporting the use of cardiac vagal activity as a marker for self-regulation under pressure. Cardiac vagal recovery was impaired by poor performance which highlighted psychophysiological relationships between performance outcome and cardiac vagal recovery.

This research makes a novel contribution to psychophysiological theory through the use of a combined approach using objective and subjective measures to predict performance. Moreover, research findings suggest phasic patterns of cardiac vagal activity may be task dependant and should be investigated further to extend current theory. From a methodological perspective, adopting a systematic approach to measuring both tonic and phasic cardiac vagal activity will help to standardize future research in the field. Finally, findings from this research will encourage practitioners to use psychophysiological measures to further understand performance under pressure.

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LIST OF ABBREVIATIONS

ANS: Autonomic Nervous System

AOSPAN: Automated Operation Span Task

CVA: Cardiac Vagal Activity

DSRS: Decision Specific Reinvestment Scale

ECG: Electrocardiogram

HFHRV: High Frequency Heart Rate Variability

HRV: Heart Rate Variability

MSRS: Movement Specific Reinvestment Scale

PNS: Parasympathetic Nervous System

RMSSD: Root Mean Square of Successive Differences

SNS: Sympathetic Nervous System

TEIQue: Trait Emotional Intelligence Questionnaire

VAS: Visual Analogue Scale

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1. GENERAL INTRODUCTION

The aim of this chapter is to identify the main conceptual areas within the thesis. It will first clarify the concept of performance under pressure which will provide the setting for this research project. The following section outlines the process of psychophysiological adaptation under pressure in line with the evolution of literature and theoretical development in the area. Subsequently, the coping related variables that can influence psychophysiological reactions and performance under pressure are discussed. The final section acknowledges how the highlighted coping related variables combine to help or hinder performance under pressure and outlines the aims of the thesis.

1.1. Performing under pressure

Within today's competitive society an individual's performance can determine their successes or failures in a number of settings such as work, education or sport (Weinberg 2010). Performance is defined as "…almost any behaviour that is directed toward task or goal accomplishment" (Campbell and Pritchard 1976, p.64). It is associated with outcomes, achievements, or results and goes beyond duties, responsibilities and competencies (Rothwell et al. 2007). As performance is outcome orientated it means that there is an element of comparison in order to determine if the outcome has been met. Often, individuals are not just comparing their results against themselves, but also others in the performance domain, which can be contextualised as competition. Church (1968) described competition as a situation whereby rewards are distributed in an unequal fashion, depending on how well the individual has performed.

When the need to produce a successful outcome is increased, then the need to perform well becomes more important, which in turn elicits performance pressure (Baumeister and Showers 1986). Baumeister's (1984) definition of pressure is one of the most widely accepted within this research domain (Stoker et al. 2017; Laborde et al.

2014a; Gardner 2012; Tanaka and Sekiya 2011; Gucciardi and Dimmock 2008; Otten 2009; Vickers and Williams 2007). He defines pressure as "any factor or combination of factors that increases the importance of performing well on a particular occasion" (Baumeister 1984, p.610). Sport lends itself to these types of occasions, for example one of the most awe-inspiring spectacles of performing well on a particular occasion is the 100m final in the Olympic games, one chance under 10 seconds to prove yourself as the fastest athlete in the world. The later definition by Baumeister and Showers in 1986 increases specificity by stating that pressure is "the presence of situational incentives for optimal, maximal or superior performance" (Baumeister and Showers 1986, p.362). Words like "optimal, maximal and superior" are all linked to successful sporting performance. For example, the marathon runner producing their "optimal" time, the weightlifter lifting their "maximal" load, the badminton player hitting a "superior" shot.

There are many sources within the competitive sporting environment that can create pressure on performance. These may include social evaluation, performance contingent rewards, threat of failure, ego threat and the risk of a one-time chance performance (Baumeister and Showers 1986). The need to cope with pressure and adapt to the environment is considered crucial in competitive sports, with greater emphasis on the presence of pressure at higher levels (Patmore 1986). There is a vast amount of research that has found that an inability to cope with pressure causes performance decrements within a sporting environment (Gucciardi and Dimmock 2008; Vickers and Williams 2007; Beilock and Carr 2001; Lewis and Linder 1997). Therefore, many researchers have investigated how individuals regulate their behaviour and reactions towards their desired goals in these environments. This process of goal directed behaviour over time and in changing circumstances is known as self-regulation, a function which involves psychophysiological processes (Karoly 1993; Thayer et al. 2009).

Attempting to regulate the pressure of the competitive environment will undoubtedly involve both psychological and physiological processes (Thayer et al. 2009). For example, an athlete will try to control their emotions when the referee makes an unfair call and attempt to slow their heart rate down before reacting to the decision. An increasing amount of research is examines psychophysiological mechanisms that directly affect performance under pressure (Moore et al. 2018; Gross et al. 2017; Laborde et al. 2015a; Laborde et al. 2015b; Laborde et al. 2014a; Tuner et al. 2013; Moore et al. 2013; Moore et al. 2012; Turner et al. 2012; Laborde et al. 2011). One particular area of interest is the connection between the brain and the heart as it has been shown to influence behaviour, which is a reciprocal relationship (Sgoifo et al. 2009). The heart-brain connection offers a theoretical basis for self-regulation and subsequent processes that may lead to better performance under pressure, such as emotion regulation (Thayer et al. 2009). These psychophysiological processes will now be discussed in more detail with regard to how they influence individuals in pressurised environments.

1.2. Psychophysiological self-regulation under pressure

Self-regulation refers to the psychophysiological processes that enable goal-directed behaviour over time and across changing circumstances. It also encompasses the processes that maintain the health of an organism (Karoly 1993; Thayer et al. 2009b). These processes are initiated when normal activity is hampered or goal-directed behaviour becomes crucial for example the appearance of a challenge (Karoly 1993). The resulting action is that the individual actively adapts in order to meet the demands of the environment (Thayer et al. 2009). Researchers have been investigating the mechanisms of internal regulation for over 150 years in order to understand how individuals cope with environmental challenges. This understanding was first derived from the seminal work of the French physiologist Claude Bernard. Bernard was particularly concerned with the internal environment of organisms and how these were regulated (Bernard 1927). He suggested that the internal environment serves to protect and nurture the functions of the body and is a stimuli that regulates the physiological phenomena during experimental investigations (Cooper 2008). This means that the internal environment of the body has a dual purpose, to both serve the inner workings of the body and to react to external stimuli. He was particularly interested in the influence of the nervous system over regulatory functions. The following quote from his laboratory notebook, *Le Cahier Rouge*, demonstrates his thoughts regarding this influence:

> *"The importance of the nervous system [is that it] communicates with the external world on the one hand, and causes the internal organs to function and establish the milieu intérieur (the environment within) in which they must live"* (Hoff et al. 1967, p. 50).

This thinking on the delicate inner balance grew into the beginnings of homeostasis and Bernard was the first researcher to develop this concept (Bernard 1927). Homeostasis is defined as "the tendency of the body to maintain a constant internal environment in the face of a changing external environment" (Bartlett et al. 2012, p. 629). The concept of homeostasis subsequently became of increasing interest to many other researchers, one of which was the American physiologist, Walter Cannon.

Cannon developed a specific interest in the autonomic nervous system (ANS) (Cooper 2008; Cannon 1929), the involuntary system which regulates internal homeostasis (Kenney et al. 2015). He started exploring the role of the ANS in emotional disturbance, particularly distress, discomfort or pain (Cooper 2008) and went on to publish his classic paper in 1929 titled "*Organisation for physiological homeostasis*" (Cannon 1929). Cannon was interested in the response to threat which is essentially the innate human programming to surviving in challenging situations (Cannon 1929). He suggested that when an individual experiences the emotion of fear it promotes the instinct to flee and when an individual experiences the emotion of anger it promotes the instinct to fight (Cannon 1929). This then became colloquially known as the “flight or fight” response and as emotional beings, humans have the ability to read the environment or “emotional landscape” and through self-regulation can generate the appropriate behaviour (Thayer and Lane 2000). Therefore the physiological response to the environment, through the ANS, provides a useful index of how the individual copes with demands faced (Levenson 2003; Thayer and Lane 2000; Porges 1992).

The ANS provides an index for the adaptation of an organism (Porges 1992) and its primary role is to involuntarily regulate internal homeostasis (Kenney et al. 2015). A secondary role is to provide an activation and deactivation system in response to the environment (Levenson 2003). To serve these roles the ANS has two branches, the sympathetic nervous system (SNS) and the parasympathetic nervous system (PNS). The SNS is the excitatory system which is innervated through the sympathetic nerves (Porges 1992). It prepares the body for impending danger or stress, is associated with physiological arousal (Kraemer et al. 2012; Karageorghis and Terry 2011) and avoids over thinking in threatening situations (Kraemer et al. 2012). The PNS is the inhibitory division and it acts a restorative system to conserve bodily energy and rest vital organs (Kenney et al. 2015), and ultimately return to homeostasis (Porges 1992). This division utilises vagal nerves to slow processes within the body such as slowing heart rate to allow the myocardium (heart muscle) to rest (Porges 1992). Together, the branches of the ANS are the body’s life support system that regulate a vast range of functions including that of cardiovascular activity (Levenson 2003).

Cardiovascular activity, in particular heart rate, has been a popular method for indexing the activity of the ANS but more specifically the influence of the nervous system on heart output (Kreibig 2010). In order to understand the nervous control of the heart a measure called heart rate variability (HRV) is used (Kreibig 2010). HRV represents the changes in time between successive heartbeats, and is also known as the inter-beat interval (Berntson et al. 1997; Camm et al. 1996; Akselrod et al. 1981). The inter-beat interval is measured through an electrocardiogram (ECG) specifically within the QRS complex which is the graphical deflection of the heartbeat (Goldberger et al. 2018).

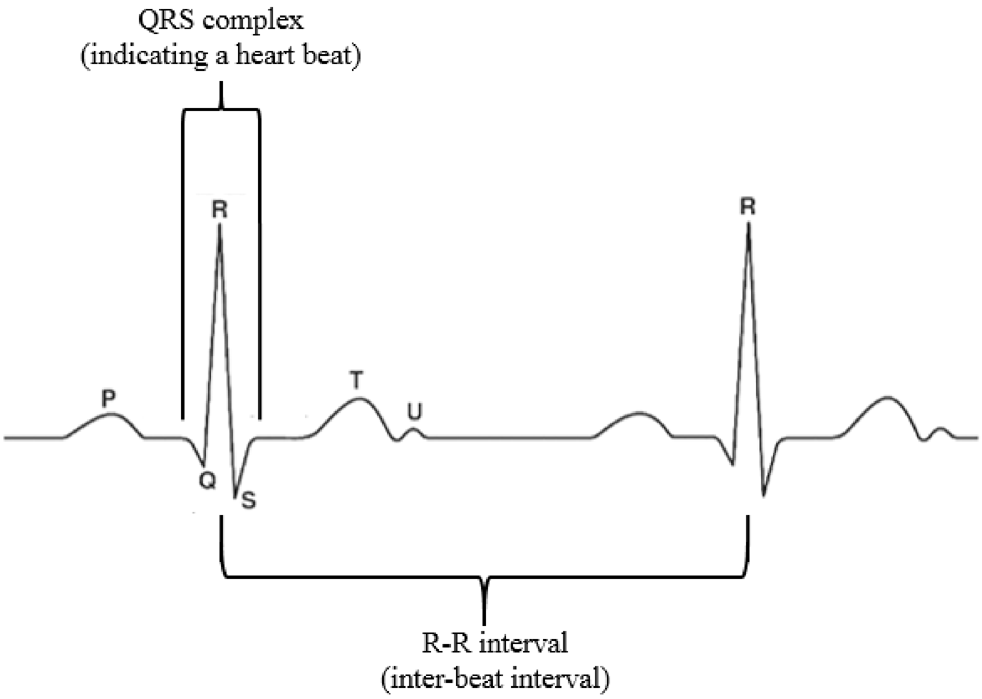

Figure 1 QRS complex (Adapted from Goldberger et al. 2018, p. 8)

The R peaks (as part of the QRS complex, which can be seen in figure 1) represent the point at which the heart beats. More specifically, the R peak represents the depolarisation of the sinoatrial node, which begins the electrical process in the heart that causes it to beat (Berntson et al. 1997; Appelhans and Luecken 2006). The time measured between the two R peaks is the inter-beat interval (Appelhans and Lucken 2006). Therefore, when the SNS is activated it has an excitatory stimulus on the sinoatrial node, and among other things, heart rate will increase; in a reciprocal fashion the PNS or vagal inferences have an inhibitory effect on the sinoatrial node which decreases heart rate (Appelhans and Luecken 2006). The changes in heart beat represent the interplay between the SNS and PNS which results in changes in inter-beat intervals which corresponds to HRV. HRV is then calculated from the instantaneous variations in heart rate using temporal inter-beat measurements and allows researchers to understand which part of the ANS is activated (Appelhans and Luecken 2006).

Activation within the SNS was previously thought to clearly identify a stress response to the environment (Malliani et al. 1991) as its role is to prepare the body for impending danger through physiological arousal (Kraemer et al. 2012; Karageorghis and Terry 2011; Cannon 1929). However, SNS dominance may not be a clear indicator of the systems adaptation to the environment (Porges 1995; Porges 1992), particularly when measured through HRV. Measures of sympathetic activity, through HRV, have been termed "dubious" due to the contamination of the measurement through other variables such as parasympathetic activity and baroreflex activity (Laborde et al. 2017; Pumprla et al. 2002; Berntson et al. 1997; Malik et al. 1996; Pomeranz et al. 1985). This means that obtaining a pure measure of sympathetic dominance through HRV is difficult and therefore reduces the validity of results gathered. Another method to assess the difference in activation between the SNS and PNS is to determine which is dominant, known as the sympatho-vagal ratio. However, similar to measuring the sympathetic system through HRV, the sympatho-vagal ratio is also generally rejected (Laborde et al. 2017; Billman 2013; Heathers 2012; Berntson et al. 2008). This is because the physiological mechanisms that underpin the sympatho-vagal ratio are unclear and thus lower predictive value and the ability to draw sound conclusions (Laborde et al. 2017; Billman 2013; Heathers 2012; Berntson et al. 2008). Therefore, measuring a response to pressure through the SNS indexed by HRV is generally rejected and also has limitations at the physiological level.

At the anatomical level, the sympathetic influence on the heart is too slow to produce beat-to-beat changes, whereas the PNS uses direct nerve fibres to innervate the heart (Jose and Collison 1970). This direct nerve stimulation of the PNS comes from the 10th cranial nerve, the vagus nerve, which is why parasympathetic activation is also known as cardiac vagal activity (Shaffer et al. 2014). There is now compelling evidence that parasympathetic activity, or cardiac vagal activity, is associated with a large range of psychological and behavioural variables (Smith et al. 2017). Therefore it is not surprising that the majority of research and key theories with regards to self-regulation and coping are underpinned by activity derived from the vagus nerve (Laborde and Mosley 2016).

1.3. Cardiac vagal activity as a measure of self-regulation

The vagus nerve has a widespread influence on the body as its fibres innervate the majority of organs, and it is composed of afferent and efferent fibres, which allows it to send information bidirectional between the body and the brain (Brodal 2010). The vagus nerve is directly linked to the central autonomic network as it has direct control over the autonomic nervous system (for details, see Benarroch 1993; Thayer et al. 2009), see figure 2.

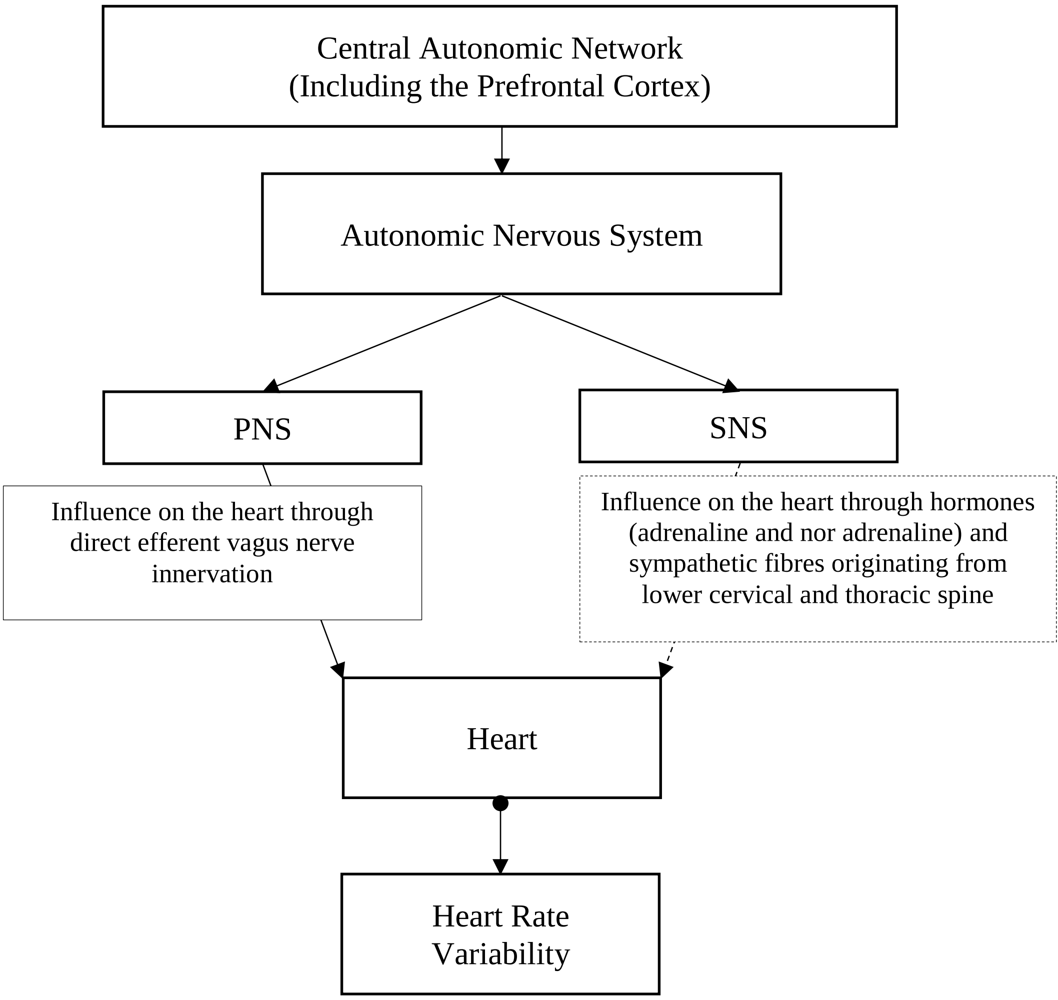

Figure 2 Graphical representation of the central autonomic network's influence on the heart

The central autonomic network is in direct control of the ANS and is involved in the moment to moment modulation of visceral functions, maintenance of homeostasis, and adaptation to internal or external challenges (Benarroch 2014). The central autonomic network has many functions across numerous areas, for example sleep and pain, but those that are directly related to performance include; the integration of bodily sensation with emotional and goal-related autonomic responses, reactions for homeostasis and adaptation and behavioural responses to stress (Benarroch 2014; Thayer et al. 2009). Therefore, it is accepted that the central autonomic network supports goal-directed behaviour and adaptability which directly influences self-regulation (Benarroch, 1993). It is also commonly accepted that vagal outputs are associated with the central processing systems involved with self-regulation (Fallen et al. 2001). Subsequently, cardiac vagal activity as a measure of self-regulation has been further validated through the theoretical work of Porges (1995) Polyvagal theory and Thayer and colleagues model of Neurovisceral Integration (Smith et al. 2017; Thayer et al. 2009).

The polyvagal theory was first developed in 1995 by Stephen Porges and the position of the theory was later updated in the Poly Vagal Perspective in 2007 and new insights added in 2009 (Porges 2009; Porges 2007; Porges 1995). This theory suggests that vagal control is associated with a human's ability to engage or disengage with their environment through the vagal system (Porges 2007). It stems from an evolutionary basis and suggests that the fight or flight behaviours are now adaptive responses to modern social environmental demands. More specifically, this model suggests that our ANS provides the psychophysiological functions to support the emotional processes that denote social behaviour such as facial expressions, communication quality, bodily and behavioural regulation (Porges 2007). The theory suggests different physiological states manifested by the vagus nerve are a means of supporting different behaviours (Porges 1995), two of which involve cardiac vagal activity. The first physiological state is a vagal withdrawal to mobilise the flight or fight system and the second is an increase in vagal activity which promotes social behaviours (Porges 1995). This has been characterised in this theory through the metaphor the "vagal brake".

The polyvagal theory suggests that during times of demand our bodies use the vagus nerve acts as a "vagal brake" in order to promote the most effective behaviours for the environment. Much like the brake on a car when the brake is applied there is a sudden halt in activity (leading to parasympathetic dominance) and when the brake is released the activation starts again (leading to sympathetic dominance). The application of the "vagal brake" causes an increase in cardiac vagal activity and the theory suggests that higher vagal activity is more facilitative when placed under environmental demand

(Porges 2007). In addition, it is suggested the application of the brake serves to foster calm behavioural states by inhibiting the sympathetic influences to the heart (Porges 2007), and therefore more desirable social behaviours, such as an inhibition of response to anger. In contrast the release of the vagal brake causes a withdrawal of the influence of the vagus nerve and therefore the sympathetic system takes dominance (Porges 1995). This withdrawal helps to support fight or flight behaviours where individuals may need to react quickly without thinking (Porges 2007), and therefore promotes functional behaviours in threatening social situations.

The polyvagal theory provides a basis for understanding the function of cardiac vagal activity as a means of understanding self-regulatory social engagement, however it is not without its limitations. Other theories suggest more direct neural pathways to influence self-regulation which includes the functional networks of the central autonomic network which represents higher order processing (Thayer et al. 2009). By excluding the higher order brain functions the polyvagal theory lacks neural underpinning which may help to understand functions that assist in self-regulation such as the regulation of emotion. In addition, the model does not offer clear predictions for how cardiac vagal activity may influence performance, it only suggests how cardiac vagal activity may serve as an influence over social behaviours.

One model that does provide clear predictions for how cardiac vagal activity may directly influence performance through self-regulation is the neurovisceral integration model (Thayer et al. 2009). This model suggests there are a group of physiological systems whose role is to serve self-regulatory processes which ultimately foster adaptation of an organism. The physiological systems highlighted in the neurovisceral integration model are grouped under the central autonomic network which includes various brain structures under the organization of the prefrontal cortex (Benarroch 1993; Thayer et al. 2009). The prefrontal cortex has many roles within self-regulation including inhibition, attention, memory processes, emotion regulation and decision making (Fuster 2015). In addition to these roles, the prefrontal cortex is involved in the perception action cycle which drives goal directed behaviour and processes information from the environment in relation to these goals (Fuster 2015). Together, this network allows information to flow bidirectionally between lower and higher levels of the central nervous system through the vagus nerve. As previously stated the central autonomic network directly influences parasympathetic innervation of the heart through the vagus nerve, with vagal influences on the heart being the dominant influence due to direct nervous stimulation (Benarraoch 2014). Therefore, the primary output of interest from the central autonomic network is cardiac vagal activity, which can be indexed by HRV. By indexing cardiac vagal activity which is manifested through activity of the vagus nerve, which is an output of the central autonomic network, it acts as a measure to suggest that there is activity in the prefrontal cortex which allows for better emotional regulation, adaptation and facilitative behavioural responses (Benarroch 2014). It is the central autonomic network including the functioning of the prefrontal cortex on which the predictions of neurovisceral integration model are built (Thayer et al. 2009).

The main proposal of the model is that individuals who have higher cardiac vagal activity have better self-regulation, adaptation and health (Thayer et al. 2009). It also offers predictions with regard to cognitive performance in demanding situations, with a specific focus on executive functions which are controlled by the prefrontal cortex (Thayer et al. 2009). Executive functions are high-level cognitive functions that serve goal-directed behaviour and are assumed to be linked to self-regulation (Hofmann et al. 2012; Barkley 2001). They are particularly important when performing in demanding environments as they involve processes such as working memory, sustained attention, behavioural inhibition and mental flexibility (Thayer et al. 2009). Those who perform well in these tasks are predicted to have higher levels of cardiac vagal activity as activity in the vagus nerve is directly linked to prefrontal functioning (Thayer et al. 2009). More specifically, the model suggested that higher levels of resting cardiac vagal activity promote effective cognitive performance (Thayer et al. 2009). The higher the levels of cardiac vagal activity before a demanding task the more likely the individual is able to effectively uptake the self-regulation resources made available through the prefrontal cortex. Conversely, those who have lower resting cardiac vagal activity before cognitive performance have been shown to perform poorly in comparison to those who have higher levels at rest (Hansen et al. 2003; Hugdahl et al. 2000).

The neurovisceral integration model provides predictions for cognitive performance however it does not provide predictions for tasks that are not solely cognitively based, such as a sporting skill. The model suggests that non-executive performance does not require higher levels of cardiac vagal activity because the task does not require higher order control (Thayer et al. 2009). However, predictions are not made for activities where multiple demands are needed such as sport where cognitive processes and motor control are important. This particular limitation of the current theory, provides a gap for new research to explore and provide an extension the neurovisceral integration model. The predictions of the neurovisceral integration model have been applied to the sporting domain through cognitively based sporting tasks under pressure (Laborde et al. 2015b; Laborde et al. 2014a). Higher levels of resting cardiac vagal activity predicted athletes' cognitive performance through simulated decision making tasks under pressure (Laborde et al. 2014a) and working memory performance under pressure (Laborde et al. 2015a). To date, the majority of studies have been limited to laboratory based studies, or studies based around simulation of competitive or real life events (Laborde et al. 2015a; Laborde et al. 2015b; Laborde et al. 2014a; Saus et al. 2012).

Another limitation of the model is that it only provides predictions for resting cardiac vagal activity. The process of self-regulation, by definition, is a constant one where the organism is adapting across time and reacting to changing environments (Karoly 1993; Thayer et al. 2009). Therefore, taking resting measures alone is not enough to understand how someone is self-regulating under pressurised situations. The model provides one prediction regarding the change in baseline to task (known as reactivity) and suggests that a large drop is negative for cognitive performance (Thayer et al. 2009). A recent review by Smith and colleagues (2017) provides an updated and expanded version of the model with greater anatomical depth and suggested new concepts to be considered. The concepts relevant to self-regulation involved how past experience may influence vagal responses to the same stimuli, context specific vagal output and situations involving metabolic demand as opposed to cognitive demand (Smith et al. 2017). These recent suggestions have been framed by the authors as a way of guiding future research (Smith et al. 2017), as these predictions are yet to be tested in relation to tonic and phasic cardiac vagal activity. Therefore, in order to build on the original models predictions, (resting levels of cardiac vagal activity), to fully understand self-regulation and ensure effective HRV data collection to reflect cardiac vagal activity, it is important to measure psychophysiological reactions across a pressurised event (Karoly 1993) and adhere to methodological guidelines (Laborde et al. 2017).

1.4. Vigilant and timely measurement of cardiac vagal activity to determine self-regulation

Prior to any HRV measurement it is essential to ensure vigilant checks are in place to avoid any confounding effects on the data. HRV is a very sensitive measure and can be effected by a number of variables ranging from factors relating to the participant, environmental conditions and data processing. A recent methodological paper from Laborde and colleagues (2017) provides an overview of considerations that are important for HRV research. With regards to the participant, stable factors such as age, gender, smoking, alcohol consumption or medication that can influence the heart need to be taken into account. In addition more transient variables should also be considered to ensure HRV measurement is valid, such as activities in the previous 24 hours before the experiment (following a normal sleep routine, intense physical training or alcohol consumption), and in the two hours leading up to the experiment (no caffeine or food). Consideration of the environment is also crucial such as temperature and body position relating to the task, for example if the task is completed in a standing position the baseline should also be conducted whilst standing as body position can influence HRV (Young and Leicht 2011). Based on these recommendations, studies using HRV need careful planning and suitable pre-screening measures to ensure reliable data (for an example of pre-screening for HRV research see appendix three).

In addition to pre-screening and correct experimental planning, data processing is an important consideration, particularly when determining self regulation. As mentioned in the previous section, cardiac vagal activity is the parameter of interest when it comes to indexing self regulation (Thayer et al. 2009). Many variables that were previously thought to index parasympathetic activity have been questioned in previous literature (Laborde et al. 2017; Billman 2013; Heathers 2012; Berntson et al. 2008; Pumprla et al. 2002; Berntson et al. 1997; Malik et al. 1996; Pomeranz et al. 1985). It is suggested that RMSSD (the root mean square of the successive differences between R-R intervals) and high frequency absolute power are the most suitable variables to assess cardiac vagal activity (Laborde et al. 2017). Additional checks for respiration must also be carried out when examining cardiac vagal activity, as controlled breathing is noted to have an influence over heart rate variability measurements (Malik 1996; Berntson et al 1997). This can be done post-hoc through the electrocardiogram derived respiration variable from Kubios, a HRV analysis software. This variable estimates respiratory frequency from the R-wave amplitudes which are known to change under chest movements related to respiration (Tarvainen et al. 2014) and is one method used to control for the effects of respiration on cardiac vagal activity (Laborde et al. 2017).

In addition to the necessary procedures, variables and post hoc checks that should be assessed to index cardiac vagal activity, it should also be strictly measured at different time points in order to understand how an individual has responded to a task (Laborde et al. 2017). When taking a measurement at a particular static time point, for example a resting five minute baseline, this is known as a tonic measure (Laborde et al. 2017). Tonic measurements are taken over a period of time to provide an average cardiac vagal activity measurement (Malik 1996). Laborde and colleagues (2017) suggest that this is taken at three stages: rest (or baseline), task and post-task which directly reflects the three R's of cardiac vagal activity: resting, reactivity and recovery (see Figure 3). Tonic measures have shown their importance and it is theorised that higher levels of resting cardiac vagal activity is more beneficial for stress management and emotional regulation (Thayer et al. 2009). However, tonic measurements alone are not sufficient to determine the adaptation of the system when demand is placed upon it (Thayer et al. 2012). Therefore, it is also important to consider the change between tonic measurements which is known as phasic cardiac vagal activity.

Phasic cardiac vagal activity can be the change from resting to a stressful task or from the stressful task to the post-task state (Park et al. 2014), which is referred to in the three R's as reactivity and recovery (Laborde et al. 2017). Cardiac vagal reactivity is further reported as the difference between resting cardiac vagal activity and task cardiac vagal activity (Laborde et al. 2017). Cardiac vagal recovery is the difference between task cardiac vagal activity and post-task cardiac vagal activity (Laborde et al. 2017). By assessing phasic cardiac vagal activity an understanding of how the individual is regulating themselves under pressure can be developed. Importantly, the levels of tonic cardiac vagal activity were found to influence phasic cardiac vagal activity (Park et al.

2014). Typically this relationship is strong and has large effect sizes for example higher tonic cardiac vagal activity at rest was associated to higher phasic cardiac vagal reactivity, $f^2 = 2.64$ (Park et al. 2014). This can be explained because tonic cardiac vagal activity, specifically resting levels, allow for better self-regulation in stressful situations according to the neurovisceral integration model (Thayer et al. 2009). Thus, it is predicted that tonic cardiac vagal activity may predict phasic cardiac vagal activity. It is crucial to use both tonic and phasic measures to understand interactions occurring at the physiological level (Laborde et al. 2017). In doing this, researchers can index self-regulation which may feed into behaviours and subsequently influence performance under pressure.

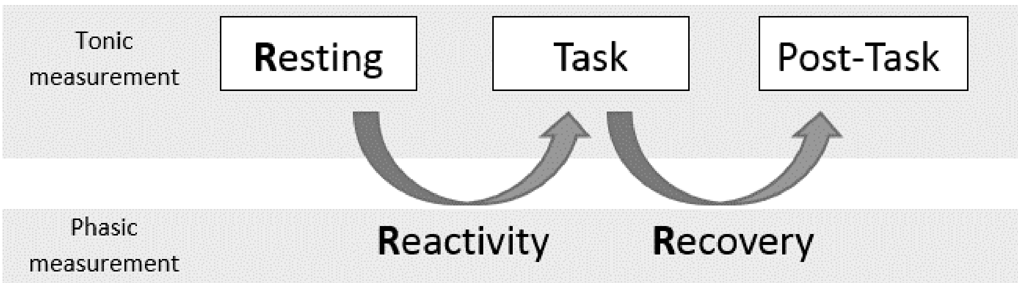

Figure 3 The three R's (Adapted from Laborde et al. 2017)

Currently there are limited theoretical predictions for phasic measures of cardiac vagal activity, with only a handful of research papers exploring the effects of these variables under pressure. Reactivity directly represents a reaction to an event or stressor and demonstrates how the individual adapts to the challenge at hand (Beauchaine et al. 2007). Reactivity can be interpreted in different ways dependant on the situation, a decrease from rest to task can be interpreted as adaptive or maladaptive depending on situational demands (Porges 2009) or if executive functioning is involved (Thayer et al. 2009). When executive function is not required, vagal withdrawal (a reduction from rest to task) shows a positive adaptation to the task in that the body is providing the individual with the resources it needs to function within that environment (Porges 2007). This has been demonstrated by Saus and colleagues (2012) where naval cadets reported their situational awareness and were split into high situational awareness and low situational awareness groups. They then took part in a sailing navigation simulation and had cardiac vagal activity measures taken before, during and after the task (Saus et al. 2012). They found that those high in situational awareness showed a reduction in cardiac vagal reactivity (from rest to task), demonstrating their ability to modulate their internal environment in order to match external demands (Saus et al. 2012).

Conversely, vagal withdrawal is seen to be negative when the task involves executive functioning (Thayer et al. 2009). This has been demonstrated in laboratory experiments examining tasks involving executive functioning. Studies by Laborde and colleagues showed that a smaller reduction in cardiac vagal reactivity from resting to task was associated to better executive performance under pressure (Laborde et al. 2015a; Laborde et al. 2014a). In addition, it has been shown that successful self-regulation during emotion regulation tasks promotes an increase in cardiac vagal activity from resting to task (Park et al. 2014). By assessing reactivity, it allows for further exploration of the psychophysiological mechanisms that underpin self-regulation above and beyond resting measures, as shown in empirical research (Laborde et al. 2015a; Park et al. 2014; Laborde et al. 2014a). Furthermore, research assessing cardiac vagal reactivity found it had relationships on other variables that directly influenced performance under pressure (Laborde et al. 2015b; Park et al. 2014; Laborde et al. 2014a), which warrants further investigation.

The final R of the three R’s model is recovery (Laborde et al. 2017). Once the demand in the environment is no longer present the organism will enter a state of recovery in order to regain homeostasis (Bartlett et al. 2012). Just as the physiological response gets turned on in order to deal with a stressful event so too does it have to be switched off again once the stressor is no longer present (McEwen 1998). Limited studies have examined cardiac vagal recovery in line with self-regulation and it is theorised that the faster the cardiac vagal recovery back to resting levels, the better the self-regulation (Stanley et al. 2013). For example, Papousek and colleagues (2010) found that the effectiveness of vagal recovery back to resting levels was worsened by less positive affect and fewer positive emotions during an academic stressor task. This suggests that those individuals who had a poor emotional reaction to the task directly affected their recovery (Papousek et al. 2010). Another study assessing levels of emotion regulation difficulties in students, found that impaired cardiac vagal recovery was linked to those who had poor emotion regulation (Berna et al. 2014). Both studies were based in laboratory environments where only one stressor was present at one time, which may not account for events with multiple stressors. The sporting domain tends to have multiple stressors over the course of one competition, and therefore being able to recover from these events is crucial to ensure performance is maintained.

The three R's structure allows for investigation at each measurement point and allows the researcher to gain physiological information for the duration of a stressful event (Laborde et al. 2017). Furthermore, it can also show the interaction between these three different physiological time points and how these may facilitate performance (Park et al. 2014). By using this systematic approach, it builds on previous theory that only account for predictions surrounding resting levels of cardiac vagal activity (Thayer et al. 2009). It also helps to further understand self-regulatory functions under pressure that may facilitate performance under pressure. In addition, it provides a methodological framework for studies to use in order to standardise results across laboratories using cardiac vagal activity to index self-regulation (Laborde et al. 2017). Therefore, the systematic application of the three R's will be used in the current thesis to understand the processes of self-regulatory efforts across performance under pressure.

Cardiac vagal activity provides an index of psychophysiological self-regulation (Thayer et al. 2009), which allows researchers to use an objective measure to better understand the adaptation of an individual when faced with a pressurised event (Thayer et al. 2009). However, by only assessing physiological reactions, research has the potential to display a biased view of the responses to the environmental demands. Certain variables at the subjective level have been shown to have direct effects on levels of cardiac vagal activity in demanding environments (Laborde et al. 2015a; Laborde et al. 2015b; Laborde et al. 2014a; Park et al. 2012; Park et al. 2013; Laborde et al. 2011). Nonetheless, very few studies have examined how cardiac vagal activity is related to the subjective experience of regulating internal and external demands when faced with the pressure to perform. Consciously appraising the demands of a situation is directly linked to the process of coping, which allows an individual to determine if they have enough resources to manage the demand effectively (Lazarus and Folkman 1984). This allows for the understanding of how conscious appraisals of coping processes are then related to the bodily processes involved in coping under pressure (Laborde et al. 2015b). Therefore, the need to understand how subjective measures of self-regulation and coping under pressure can directly affect physiological output is crucial (Mosley and Laborde 2016; Mosley and Laborde 2015). In doing this a more holistic understanding of the psychophysiological processes involved with self-regulating under pressure can be achieved (Mosley and Laborde 2016; Mosley and Laborde 2015).

1.5. Coping related variables influencing cardiac vagal activity

Coping related variables was a concept coined by Laborde and colleagues in 2015 when they examined a range of variables from different domains in line with cardiac vagal activity. Although they did not directly define this concept, they included variables that are deemed to have a direct effect on the coping process, but may not be directly linked to more traditional measures of coping such as coping styles (Laborde et al. 2015b). When coping styles have been examined in line with cardiac vagal activity there were no associations found (Martin et al. 2011) or unclear findings (Ramaekers et al. 1998). Therefore, this may suggest that coping may be a more indirect mechanism associated with the psychophysiological process of coping, but again this has rarely been explored under pressure.

These indirect mechanisms largely come from measurements in both the trait and state domains. Traits provide a stable indicator of coping as they are unlikely to change across a range of situations (Pervin 1996) and have been shown to predict performance under pressure (Guekes et al. 2017; Laborde et al. 2015a; Guekes et al. 2013). States provide a dynamic indicator of coping through attending to relevant cues within the environment and conscious appraisals of the situation at hand (Lazarus and Folkman 1984). Currently, there are only a handful of studies that have examined variables that may affect the coping process in line with cardiac vagal activity (Laborde et al. 2015a; Laborde et al. 2015b; Laborde et al. 2014a; Park et al. 2013; Park et al. 2012). Table 1 below outlines the studies of relevant interest which are directly linked to mechanisms of coping and self-regulation and cardiac vagal activity in performance under pressure. Following the table, the coping related variables (trait emotional intelligence, reinvestment, appraisals and attention) are discussed in turn including a theoretical background to the variable and secondly the variables links to cardiac vagal activity.

Table 1 Studies assessing coping related variables and cardiac vagal activity under pressure

Authors, date and study name	Coping related variables	Participants	Task	Pressure manipulation	Effects on CVA	Performance
Park, G., Bavel, J., Vasey, M, and Thayer, J., 2012. Cardiac vagal tone predicts inhibited attention to fearful faces.	- Attention (performance) - Cardiac vagal activity (Resting)	45 undergraduate students	Selective attention and inhibition (inhibition of return task)	- Participants were told they must complete the task as quickly and as accurately as possible - When participants had taken too long to answer, given negative feedback - Closely video-monitored	- Higher resting cardiac vagal activity allowed for better attentional capacity, indicated by cue validity (η^2 = .38) - When high and low cardiac vagal activity groups were compared, low participants were slower (*d* = .78)	- High resting cardiac vagal activity was associated with superior performance, through the ability to inhibit attention to fearful distractors (*d* = .75)
Park, G., Vasey, M., Bavel, J., and Thayer, J., 2013. Cardiac vagal tone is correlated with selective attention to neutral distractors under load.	- Attention (performance) - Cardiac vagal activity (Resting)	77 undergraduate students	Selective attention (letter detection task with fearful and neutral distractors)	- Participants were told they must complete the task as quickly and as accurately as possible - When participants had taken too long to answer, given negative feedback - High and low perceptual load conditions	- Higher resting cardiac vagal activity was associated to more effective attentional strategy under load (η^2 = .10)	- Those who had lower resting cardiac vagal activity were slower in the trials in both fearful and neutral conditions - Higher cardiac vagal activity was associated to faster performance in neutral under high load (η^2 = .10)

Laborde, S., and Raab, M., 2014a. Is the ability to keep your mind sharp under pressure reflected in your heart? Evidence for the neurophysiological basis of decision reinvestment.	- Decision reinvestment - Cardiac vagal activity (resting, task, reactivity)	42 male sport science students	Decision making (Sport specific option generation task)	<u>Low pressure:</u> - Read a concentration chapter <u>High pressure:</u> - Competition to win sports tickets - Competition ranking displayed at the university - Crowd noise and negative imagery - Performance contingent feedback (green light and applause for correct, red light and booing)	- High reinvestors suffered a greater cardiac vagal withdrawal from rest to task in the high pressure condition (partial η^2 = .19)	- Low reinvestors had faster decision making than high reinvestors in the high pressure condition (decision time, partial η^2 =.38, generation time, partial η^2 = .25)
Laborde, S., Furley, P., and Schempp, C., 2015a. The relationship between working memory, reinvestment and heart rate variability.	- Decision reinvestment - Movement reinvestment - Cardiac vagal activity (resting, task, reactivity)	62 university students	Working memory (Automated operation span task)	<u>Low pressure:</u> - Could win a massage voucher <u>High pressure:</u> - Told the test reflected general intelligence - Results to be displayed at the university - Percentage accuracy displayed while performing - Second experimenter took observations during the task	- Higher levels of decision reinvestment were negatively correlated to the amount of cardiac vagal activity at the end of the high pressure condition only (not reported in the paper, but a significant observation in the correlation matrix (r = -.32)	- Decision reinvestment negatively influences working memory scores in the high pressure condition only (r = -.27) - Resting cardiac vagal activity predicted working memory performance above and beyond decision reinvestment (R^2 = .13)

Laborde, S., Lautenbach, F., and Allen, S., 2015b. The contribution of coping related variables and heart rate variability to visual search performance under pressure.	- Trait emotional intelligence - Coping style - Coping effectiveness - Cardiac vagal activity (resting, task, reactivity) - Perceived stress intensity and controllability - Attention direction - Challenge and threat appraisal	96 male sport science students and actively competing in sport	Visual search (concentration grid)	- Competing to win tickets to a local sports event - Results would be made public on campus - Researcher took observations during the task	- Trait emotional intelligence (wellbeing) positively influence resting cardiac vagal activity (adjusted R^2 = .03) - Trait emotional intelligence (emotionality) (adjusted R^2 = .05) and coping effectiveness (adjusted R^2 = .17) positively influences task cardiac vagal activity - Threat appraisal negatively effects task cardiac vagal activity (adjusted R^2 = .03) - Threat appraisal associated to greater reduction in cardiac vagal reactivity (adjusted R^2 = .07)	- Threat appraisal, specifically perceived demands, reduced visual search performance (adjusted R^2 = .09) - Attention towards the body and task promoted better visual search performance (adjusted R^2 = .04)

1.5.1. Trait emotional intelligence

Trait emotional intelligence is considered a personality trait rather than a cognitive ability and involves self-perceptions which embrace the subjective nature of emotion (Petrides et al. 2007). More specifically, it is defined as a constellation of emotional self-perceptions situated at the lower levels of personality hierarchies and it is made up of four main factors: well-being, self-control, emotionality and sociability (Petrides et al. 2007). Trait emotional intelligence refers to dispositions that are emotionally related, thus causing tendencies to behave in a predetermined manner in emotional situations (Nelis et al. 2009), therefore making it an interesting trait to examine under pressure. When in emotionally charged situations, such as pressure, individuals high in trait emotional intelligence are said to effectively control and modify emotions through implementing strategies, a process known as emotion regulation (Gross and Thompson 2007). By successfully regulating emotions, trait emotional intelligence positively influences emotion regulation which promotes beneficial effects including coping under stress (Laborde et al. 2011). As emotion regulation can be indexed by cardiac vagal activity (Thayer et al. 2009; Porges 2007), trait emotional intelligence has been investigated at the neurophysiological level.

Individuals who have high trait emotional intelligence have exhibited more facilitative autonomic responses to stress (Laborde et al. 2011). Laborde et al. (2011) examined athletes under laboratory educed stress, including negative imagery and crowd noise. They found that athletes lower in trait emotional intelligence had a higher increase in sympatho-vagal ratio, which is considered as an indicator of mental stress (Kristalboneh et al. 1995), than their higher trait emotional intelligence counterparts. This suggests that athletes higher in trait emotional intelligence have better emotional regulation and therefore have a more functional physiological response to stress. The validity of the results could, however, be questioned considering the lack of support for the sympatho-vagal ratio within the current literature (Laborde et al. 2017; Billman 2013; Heathers 2012; Berntson 2008). More recent work by Laborde (2015) found that trait emotional intelligence wellbeing was the best predictor of baseline cardiac vagal activity, although this accounted for a small effect (adjusted R^2 = .03). The finding is in line with previous research examining resting cardiac vagal activity and wellbeing at rest (Geisler et al. 2010). Wellbeing is associated with positive moods and a satisfaction with life (Geisler et al. 2010), a generalised sense of wellbeing can be assumed to be a result of effective self-regulation and therefore the link to higher levels of cardiac vagal activity makes theoretical sense (Thayer et al. 2009).

When faced with a pressurised visual search task, participants high in trait emotional intelligence (emotionality) displayed higher cardiac vagal activity during the pressure task. This suggests those who were better able to understand their own emotions, thus high in emotionality, had higher levels of cardiac vagal activity and therefore were better able to regulate their emotional response to the stressful task (Laborde et al. 2015b). This supports Laborde and colleagues' (2011) previous work and suggests that those higher in trait emotional intelligence, the dimension of emotionality in particular, can better regulate emotions under pressure which in turn can facilitate performance (Laborde et al. 2015b). Similar to wellbeing, the effect size for this finding were small, (adjusted R^2 = .05), so this could suggest that trait emotional intelligence and cardiac vagal activity typically produce small effects. A limitation of the study is that only tonic and reactivity measures of cardiac vagal activity were used and therefore the phasic changes from the removal of the stressor were not accounted for. In addition, this study only examined high pressure and did not account for a baseline measure of performance or a comparative low pressure, which have been used in other studies of this nature (Laborde et al. 2015b; Laborde et al. 2014a). This is important to understand the relevance of self-regulation when faced with differing demands. Therefore, the implementation of comparative low and high pressure conditions will be adopted in the thesis.

1.5.2. Reinvestment (movement and decision)

Masters and Maxwell (2004) define reinvestment as the “manipulation of conscious, explicit, rule based knowledge, by working memory, to control the mechanics of ones movements during motor output” (p. 208). Within a pressurised environment, an individual high in reinvestment will attempt to gain conscious control of their performance which was previously autonomous causing performance disruption (Masters 1992). This regression to conscious control has been associated with a tendency to choke under pressure (Masters & Maxwell, 2008), which is evidence to suggest the individual has not coped efficiently with pressure. In addition, reinvestment clogs the mind with unnecessary thoughts, saturating working memory and therefore reduces the amount of resources available for coping (Kinrade et al. 2010; Laborde et al. 2014a).

As a concept, reinvestment has seen some development over the past two decades. Originally it was developed as a global concept, which was then established into the motor component discussed above (Masters 1992). More recently a cognitive component was founded (Kinrade et al. 2010). In line with the cognitive component of reinvestment, a recent development in decision reinvestment brings to light the nature of reinvestment in cognitive processes in decision making (Kinrade et al. 2010). Decision reinvestment is defined as overthinking, through consciously controlling thoughts and/or ruminative thoughts, which is caused by investigating high levels of cognitive effort that negatively affects performance (Kinrade et al. 2010). Both types of reinvestment can cause performance decrements under pressure which has been found in pressure research (Laborde et al. 2015a; Laborde et al. 2014a; Malhotra et al. 2012; Kinrade et al. 2010; Mullen et al. 2007; Gray 2004; Hardy et al. 2001). Therefore, reinvestment has both cognitive and movement related effects on performance under pressure.

Only two studies have examined the link between the reinvestment traits and cardiac vagal activity (Laborde et al. 2015a; Laborde et al. 2014a). The first examined decision reinvestment, cardiac vagal activity and decision making under pressure (Laborde et al. 2014a). Results showed that those higher in decision reinvestment took longer to make a decision in a high pressure condition, which may be linked to the conscious monitoring of thoughts slowing the decision process (Kinrade et al. 2010). In addition, cardiac vagal reactivity was withdrawn (a larger decrease from resting to task) in the high pressure condition for high reinvestors (Laborde et al. 2014a), which may have led to a less effective cognitive functioning during the task (Thayer et al. 2009). This was shown to have a large effect size (partial η^2 = .19) and this supports the need to understand the difference between high and low pressure conditions as some effects on performance and underlying psychophysiology may be present when higher demands are present. This also suggests those higher in decision reinvestment suffer greater decreases in cardiac vagal activity when faced with pressure related to decision making.

The second study examined both decision and movement reinvestment together with cardiac vagal activity regarding their relationship with working memory performance (Laborde et al. 2015a). They found that high levels of decision reinvestment and resting cardiac vagal activity were negatively related to working memory performance. Moreover, cardiac vagal activity predicted working memory performance over and above reinvestment (Laborde et al. 2015a), which again was found with medium effect (R^2 = .13). This demonstrates the underlying importance of using a combination of both self-reported subjective variables and objective physiological variables when predicting performance under pressure. There were no findings related to movement reinvestment, however the task was cognitively driven and movement reinvestment requires movement to be present in order to have an effect. Therefore, this needs to be investigated in line with tasks that involve movement to draw sound conclusions. In addition, the effects of reinvestment were not assessed in line with cardiac vagal recovery, given that decision reinvestment causes an individual to look back on their decisions (Kinrade et al. 2010), this would be an important avenue for further research.

1.5.3. Cognitive appraisal

Cognitive appraisals in the style of threat and challenge are defined as "dispositions to appraise ongoing relationships with the environment consistently in one way or another" (Lazarus, 1991, p. 138). When under pressure, if it is perceived that there are not enough resources to cope with the demands of the environment a threat appraisal is reached (Seery 2011). Conversely, if the perception of the environment that there are enough resources to meet or exceed the demands, a challenge appraisal is reached (Seery 2011). A challenge appraisal is associated with higher controllability of stress and therefore a greater perception of resources to cope with the task at hand (Seery 2011). This notion was developed into a psychophysiological model to represent the effects that challenge and threat appraisals have on human physiology, this theory is the bio psychosocial theory of challenge and threat (Blascovich and Mendes 2000; Blascovich and 1996). Challenge and threat states are theoretically linked to cardiovascular related measures such as cardiac output, stroke volume and total peripheral resistance (Blascovich and Mendes 2000). Empirical research has shown that challenge and threat states, particularly cardiovascular reactivity, can predict sports performance in stressful environments (Moore et al. 2013; Turner et al. 2013; Turner et al. 2012). This suggests that the appraisal process directly affects the physiological response to stressful situations and that those who respond with a challenge state may experience better performance.

To appraise environmental demands in an adaptive manner requires prefrontal regulation of emotions and therefore this process can be indexed through cardiac vagal activity (Leon et al. 2009). Cardiac vagal activity has been directly examined in line with the appraisal process with emotion (Leon et al. 2009) and through reappraisal training

(Denson et al. 2011). However, only one study has examined the relationship between challenge and threat appraisals and cardiac vagal activity under pressure (Laborde et al. 2015b). Laborde et al. (2015b) found that cardiac vagal activity increased when the individual appraised the situation as a challenge and decreased when the individual appraised the situation as a threat (adjusted R^2 = .07). This suggests that the appraisal state is associated with an individual's capacity for regulating emotional responding as indexed by cardiac vagal activity (Laborde et al. 2015b). Therefore, if an individual perceives the situation as a challenge they are more likely to have better emotional regulation and consequently higher levels of parasympathetic activity, which may result in superior performance to those who perceive the situation as a threat. This does suggest that challenge and threat appraisals may have links with the physiological processes involved with self-regulation, which warrants further investigation.

1.5.4. Attention

Attention is a cognitive system that facilitates the selection or inhibition of information that is relevant or irrelevant for future processing (Smith and Kosslyn 2007). The role of attention when predicting the breakdown of performance under pressure is a key element of pressure theories, namely distraction (Eysenck et al. 2007; Eysenck and Calvo 1992) and self focus (Masters 1992). If attention is directed away from the task due to external distractions it is said to negatively influence the capacity to perform (Eysenck et al. 2007; Eysenck and Calvo 1992). Similarly, if attention is directed towards the self, reinvestment can occur which reduces the capacity to perform (Masters 1992). Therefore, the direction of attention is important when coping under pressure as it allows for the selective allocation of resources to cope with demands (Rensink 2015). Attention towards the task is said to be linked to task orientated coping, attention directed away from the task is said to reflect disengagement coping (Laborde et al. 2015b). Moreover, attention is regarded as being under executive control, which can be indexed through cardiac vagal activity (Thayer et al. 2009).

Consistent findings from the literature demonstrate the link between attention and cardiac vagal activity (Hansen et al. 2003; Porges 1992). Attention and cardiac vagal activity have been examined in situations of pressure and cognitive load by Park and colleagues (Park et al. 2013; Park et al. 2012). Park et al. (2012) demonstrated that in an inhibition based task, where participants had to ignore visual cues of fearful or neutral faces. It showed that those who had low resting cardiac vagal activity were more distracted in the task and those who had high resting cardiac vagal activity had superior inhibitory attentional mechanisms (Park et al. 2012). Park et al. (2013) used a letter detection task where participants had to ignore fearful and neutral distractors (faces) and only respond to specific letters which appeared on the faces X and N. They found that participants who had high resting cardiac vagal activity were better able to regulate their attentional strategy and produced superior performance (Park et al. 2013). However, those low in resting cardiac vagal activity were shown to have slower and less successful performance and therefore were not able to successfully manage their attentional strategy under load (Park et al. 2013). The current findings suggest that individuals with higher levels of cardiac vagal activity are better able to control their selective attention for goal directed behaviour (Park et al. 2013; Park et al. 2012).

The studies of Park and colleagues studies assess attention through the performance of selective attention tasks which were directly linked to cardiac vagal activity (Park et al 2013; Park et al 2012). The relationship between attention and resting cardiac vagal activity have large effects as shown in Park et al. (2012) $\eta^2 = .38$ and moderate in Park et al. (2013) $\eta^2 = .10$. However, when attention was measured subjectively in line with cardiac vagal activity it only influenced performance and not cardiac vagal activity patterns (Laborde et al 2015). Limited research has been carried out to assess the role of attention in coping and its effects on cardiac vagal activity under pressure. As the direction of attention for coping is deemed to be a subjective process to allocate resources (Rensink 2015), which facilitates performance (Laborde et al 2015), it should be investigated further. Some limitations of the studies, particularly the methodological approaches of these studies are lab based which is far removed from sporting pressure situations and should be replicated in ecological settings. In addition, they did not use any phasic measures to understand the attention and the adaptation of the psychophysiological self-regulation under stress as they only examined resting cardiac vagal activity.

1.6. The contribution of coping related variables and cardiac vagal activity to predict performance under pressure

It has been demonstrated through the different coping related variables that they may influence cardiac vagal activity under pressure (Laborde et al. 2015b; Laborde et al. 2014a; Laborde et al. 2014a). Individually these variables have their own facilitative or debilitative influence over the psychophysiological process involved in self-regulation under pressure. For example, a higher resting level of cardiac vagal activity is promoted through trait emotional intelligence (Laborde et al. 2015b) or a reduction in task cardiac vagal activity is observed if the individual is high in decision reinvestment (Laborde et al. 2014a). These variables have also been shown to directly affect performance under pressure again through facilitative patterns such as approaching competition as a challenge (Moore et al. 2013; Moore et al. 2012) or debilitative tendencies such as overthinking (Laborde et al. 2014a; Malhotra et al. 2012; Kinrade et al. 2010; Mullen et al. 2007; Gray 2004; Hardy et al. 2001). It is expected that the relationship between trait measures and cardiac vagal activity will have small effect sizes whereas subjective measures will be medium. These variables may also have predictive abilities when combined and therefore when it comes to predicting performance it may be that a combination of variables hold the answer.

Combining both cardiac vagal activity and psychological coping related variables to predict performance has currently only been explored within the highlighted studies (Laborde et al. 2015a; Laborde et al. 2015b; Laborde et al. 2014a; Park et al. 2013; Park et al. 2012). Four types of performance have been addressed, including decision making (Laborde et al. 2014a), working memory (Laborde et al. 2015b), attention (Park et al. 2013; Park et al. 2012), and visual search (Laborde et al. 2015b). When predicting decision making performance, higher levels of decision reinvestment were associated to slower decision making reactions (Laborde et al. 2014a), this was also linked a greater reduction in cardiac vagal reactivity from baseline to task which may have also negatively influenced performance (Laborde et al. 2014). Decision reinvestment was also found to affect performance in the later study by Laborde and colleagues (2015a), however resting cardiac vagal activity came out as the dominant predictor of working memory performance (Laborde et al. 2015a). Attentional performance was predicted by higher levels of cardiac vagal activity at rest (Park et al. 2012; Park et al. 2013). When predicting visual search performance, attention towards the task and threat appraisal predicted performance (Laborde et al. 2015b). Although there were no associations to performance and cardiac vagal activity in this study, a threat appraisal was also associated to a reduced amount of task cardiac vagal activity and promoted a decrease in cardiac vagal activity from baseline to task (Laborde et al. 2015). This suggests that although threat appraisal did ultimately predict performance, it also had important effects on cardiac vagal activity throughout the pressure task.

Currently it is clear that both coping related variables and cardiac vagal activity play a role when predicting performance under pressure. An important consideration is that coping related variables may affect physiological reactions in pressurised situations which may indirectly affect performance, which has been a consistent finding (Laborde et al. 2015b; Laborde et al. 2014a). Although there have been consistent findings there are varying effect sizes for the prediction of performance when using multiple variables. For example, decision reinvestment predicted decision making with large effect η^2 =.38, resting cardiac vagal activity predicted attention based performance with medium effect η^2 = .10 and subjective attention promoted better visual search performance with small effect (adjusted R^2 = .04). Therefore, if variables are combined it may help to understand which of the variables influence performance with greatest statistical effect.

The current knowledge, however, is not without its limitations, perhaps the most apparent is the focus on cognitive performance. The studies of interest are grounded within a sporting domain either through the use of sport students as a sample or through using sports specific cognitive tasks (Laborde et al. 2015a; Laborde et al. 2014a) or through the use of cognitive abilities that are important for sport (Laborde et al. 2015b; Park et al. 2014). By assessing the combination of variables in more ecologically valid settings a better understanding of performance may be reached, which will have a number of benefits. From a theoretical perspective it will further the current theoretical standpoints within this area as the Poly vagal theory only provides predictions surrounding social behaviour (Porges 2009) and the neurovisceral integration model only provides predictions for cognitive tasks, particularly executive function (Thayer et al. 2009). From an applied standpoint, using tasks that are more closely linked to the sporting domain such as psychomotor tasks or sport specific tasks, would allow for a better understanding of how these variables predict above and beyond the realms of cognitive performance. This would allow practitioners to grasp which are the most useful variables to assess and develop for the purposes of performing under pressure.

Another limitation of current knowledge is that the coping related variables have either been studied in isolation or small groups alongside cardiac vagal activity. This makes it difficult to generalise the findings across the wider spectrum of variables that can directly affect both performance under pressure and cardiac vagal activity. For example, trait emotional intelligence has been shown to produce facilitative cardiac vagal activity reactions under pressure (Laborde et al. 2015b) whereas decision reinvestment can have debilitative effects on cardiac vagal activity (Laborde et al. 2015a; Laborde et al. 2014a). Exploring these elements together may provide greater understand of how factors may compete with each other to effect physiological reactions under pressure. Theoretically this is yet to be explored and would further enhance the knowledge around coping related variables and cardiac vagal activity under pressure. Holistically combining variables may offer a new methodological avenue for future research, particularly if the variables are found to interact with each other to either predict cardiac vagal activity or performance. From the applied perspective, understanding which characteristics are the most successful for performance is crucial as this may help to enhance talent identification or even the development of favourable attributes, such as emotional intelligence training (Campo et al. 2016).

A further weakness of the current body of knowledge is the inconsistent use of pressure manipulations, regarding type of manipulation and the use of both low and high pressure conditions. Some studies use both low and high pressure conditions (Laborde et al. 2015a; Laborde et al. 2014a) whereas others only use a high pressure condition without a comparative condition (Laborde et al. 2015b). Using low and high pressure manipulations allows for comparison of predictors across different situations (Geukes et al. 2017; Guekes et al. 2013). This is particularly important as some variables may have more influence in different situations for example the effects of reinvestment are said to only be present within high pressure situations (Masters 1992), which has been shown empirically in this field (Laborde et al. 2015a; Laborde et al. 2014a). Therefore, from a theoretical perspective the standardization of pressure manipulation across the same set of variables will allow for sound conclusions to be made regarding levels of pressure. From a methodological perspective using a within-subject design not only provides benefits of testing in different pressure conditions but also for measuring cardiac vagal activity (Quintana et al. 2014). Within subject designs are recommended in heart rate variability research as it allows for optimal experimental control, reduces individual differences in respiratory rate, requires fewer participants and reduces the impact of external variables such as sleep (Laborde et al. 2017; Quintana et al. 2014).

Finally, the last research gap combining coping related variables with cardiac vagal activity is the inconsistent application of the three R's of cardiac vagal activity. The three R's have recently been solidified within cardiac vagal activity research by Laborde, Mosley and Thayer (2017). Within this paper they call for the need to consistently use this methodological approach within research to ensure, particularly when investigating self-regulation under pressure, the full spectrum of psychophysiological reactions is captured (Laborde et al. 2017). Studies do acknowledge the need for tonic and phasic variables of cardiac vagal activity to be included mainly resting (Park et al. 2012; Park et al. 2013) and task and reactivity (Laborde et al. 2015a; Laborde et al. 2015b; Laborde et al. 2014a). However, the systematic application of this method is not consistent and therefore it is difficult to draw clear patterns within the research. In addition, when examining the sporting domain recovery plays an important role when faced with multiple stressors, such as breaks in tennis. Theoretically and methodologically this will allow for a clear structure for future experiments of this nature and therefore predictions for performance under pressure can be built off consistent replication of the same framework.

In conclusion, the current knowledge in this field has started to build an understanding of how coping related variables may affect cardiac vagal activity and how the combination of these variables may link together in order to predict performance under pressure. This thesis will add to the current knowledge surrounding this field from the theoretical, methodological and applied perspectives. Theory will be advanced through the systematic examination of a combination of coping related variables on cardiac vagal activity and performance under pressure. In addition, theoretical frameworks can be updated through the use of tasks going beyond cognitive performance and moving towards sport specific tasks. From a methodological standpoint, the systematic application of the three R's model throughout the studies in this thesis will begin a process of standardizing cardiac vagal activity research (Laborde et al. 2017). In addition, it will allow for a better understanding of what psychophysiological processes happen across a pressurised event, from both single time points (tonic) to adaptation (phasic) (Laborde et al. 2017). Finally, at the applied level the understanding of which characteristics are the most successful for performance is crucial as this may help to enhance talent identification or even the development of favourable attributes, such as emotional intelligence training (Campo et al. 2016). In addition, using psychophysiological practices in applied work will help to broaden the horizons of the high performance community through holistic practice.

1.7. Aims and objectives of the thesis

As a result of the literature review process and conclusions drawn, this thesis is motivated by two main aims:

1) To understand the contribution of coping related variables (cardiac vagal activity, trait emotional intelligence, reinvestment, challenge and threat appraisal and attention) on cardiac vagal activity throughout a pressurised task.
2) To understand the contribution of coping related variables (cardiac vagal activity, trait emotional intelligence, reinvestment, challenge and threat appraisal and attention) on performance under pressure.

These aims will be facilitated by the following objectives:

1) To determine the changes in cardiac vagal activity across different points during performance under pressure, specifically resting, task, post-task, reactivity and recovery.
2) To ascertain the role of both trait and state coping related variables on cardiac vagal activity and performance within pressurised environments.
3) To critically understand the predictive ability of the coping related variables on performance in both low and high pressure conditions.
4) To determine the differences in predictive coping related variables across three performance types: cognitive, psychomotor and sport specific.

1.8. Structure of the experimental studies

This thesis will present three experimentally driven studies that originate from a positivist perspective. Each study has been designed with a purposeful progression of task complexity from cognitive, psycho-motor and sport specific in order to draw conclusions across different task demands. Study one starts within the cognitive domain of performance as previous research combining coping related variables has drawn on tasks testing executive functions, because of the predictions of the neurovisceral integration model (Thayer et al. 2009). However, few and inconsistent combinations of variables exist across cognitive performance (Laborde et al. 2015a; Laborde et al. 2015b; Laborde et al. 2014a; Park et al. 2013; Park et al. 2012), thus providing an empirical base to build upon in the first study.

Study two addresses the research gap further by extending isolated cognitive performance through adding motor processes, in order to bring findings closer to the applied environment. Sporting environments often encompass the athlete performing multiple tasks simultaneously (Huang and Mercer 2001), which tend to involve both physical motor actions and cognitive processes. Therefore, study two assessed a psychomotor task to explore the coordination of sensory or cognitive processes and a motor activity under pressure (Zillmer et al. 2008). Finally study three brings the research closer to sporting performance by using a sport specific task based around a sporting competition. In doing this the final study increases ecological validity and enables practical recommendations to be drawn within field based settings.

With regard to task choice for the three studies, this was influenced by the previous literature as discussed above and with amount of movement produced during execution, because excessive movement influences HRV readings (Laborde et al. 2017). In addition, tasks also needed to have previous evidence showing sensitivity to pressure manipulations or shown to be linked to performance decrements under pressure as demonstrated above. Therefore, chapter two explores working memory performance, chapter three explores dart throwing performance and chapter four explores prone rifle shooting performance, all executed within pressurised environments. These pressurised environments needed to be similar in order to draw understanding from three different performance contexts. To ensure similarity and consistency across the three studies, an overarching methodology was designed.

The overarching methodology was a repeated measures within subject design. Within subject designs are recommended in heart rate variability research as it allows for optimal experimental control, reduces individual differences in respiratory rate, requires fewer participants and reduces the impact of external variables such as sleep (Quintana et al. 2014). A repeated measures design facilitated participants to perform the same task across two different pressure conditions, low and high, which were counterbalanced. This allowed for direct comparisons between low and high pressure conditions, which was not consistently compared across previous research. The pressure manipulations were developed in line with Baumiesters' (1984) recommendations and previous research in this area. The manipulations were extensively piloted to ensure they would be successful, this included generic development and piloting of the manipulations and each task was individually piloted with the adjusted manipulations. A developmental grid of manipulations and scripts that were delivered can be seen in appendix one.

Each study is discussed individually as separate entities in chapters two, three and four, because an overarching methodology was used there may be some repetition in the layout of these chapters. In the final chapter, chapter five, the findings of all three studies are brought together to clearly outline the broader contribution of the PhD thesis. An outline of the thesis can be seen in figure 4.

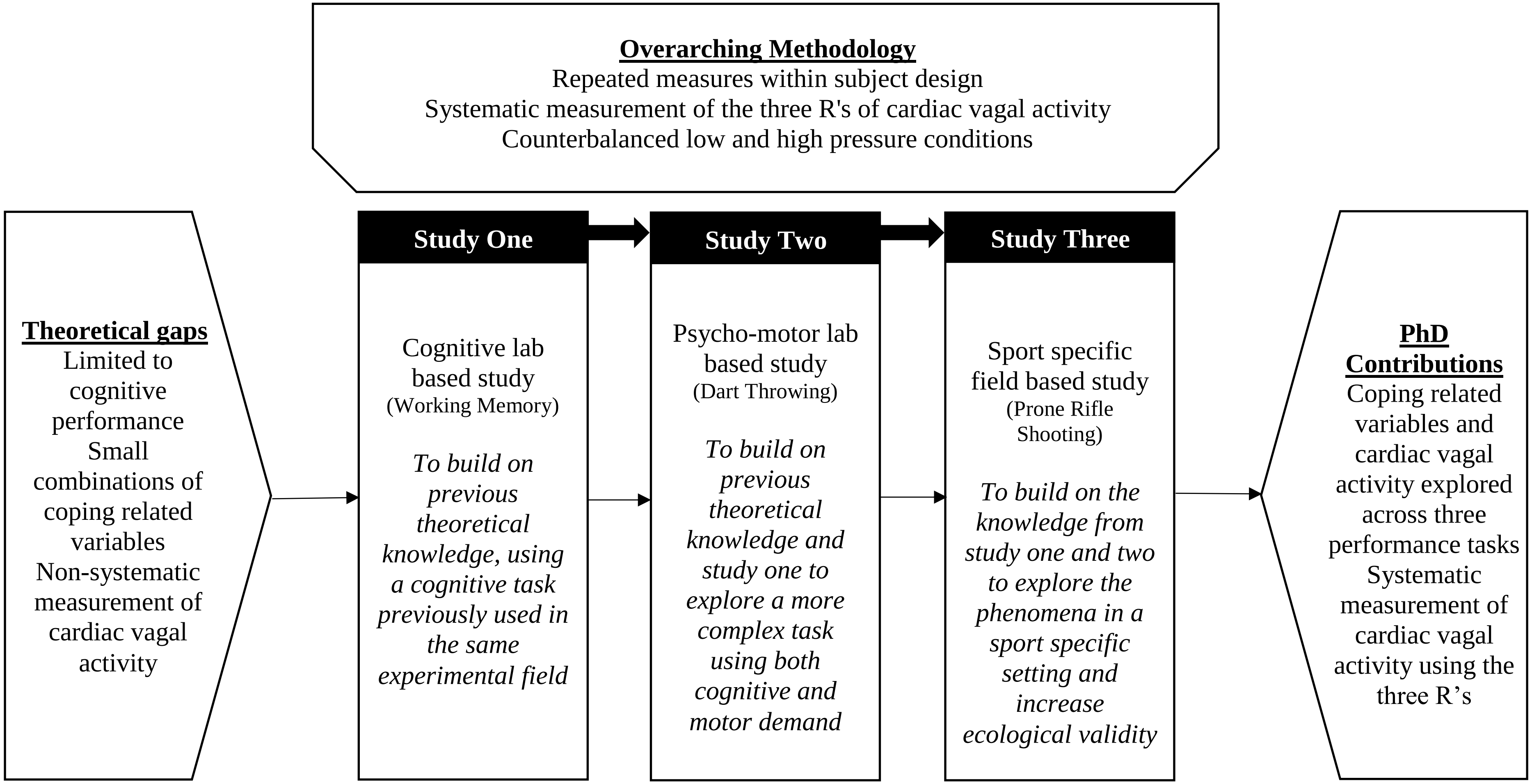

Figure 4 Structure of the experimental studies

2. COPING RELATED VARIABLES, CARDIAC VAGAL ACTIVITY AND WORKING MEMORY PERFORMANCE UNDER PRESSURE

2.1. Introduction

Chapter one outlined the psychophysiological basis of self-regulation under pressure through cardiac vagal activity. The chapter also detailed how coping related variables may influence levels of cardiac vagal activity during pressurised tasks, and subsequently how both subjective and objective variables combine to influence performance. It was highlighted that many of the coping related variables had not been combined in previous research, and therefore the relationships between these variables and cardiac vagal activity under pressure were not known. Some relationships have been examined in line with cognitive performance (Laborde et al. 2015a; Laborde et al. 2015b; Laborde et al. 2014a; Park et al. 2013; Park et al. 2012), thus providing an empirical base to build upon in the current chapter, which details the first of three empirical studies. Therefore, study one explores the influence of coping related variables and cardiac vagal activity on cognitive performance.

Pressure, which is caused by factors that increase the need to perform well on a particular occasion (Baumeister 1984), can have negative effects on a range of cognitive functions (Laborde et al. 2015a; Tomaka et al. 1993). When individuals are faced with pressure, cognitive performance is often impaired and this can lead to performance decrements (Laborde et al. 2015a; Navarro et al. 2012; Beilock and Carr 2005). These performance decrements triggered by pressure, such as impaired decision making (Laborde et al. 2014a), can subsequently lead to a break down or even failure in skill execution. One cognitive function that has been linked to skill failure under pressure is working memory, an executive function that involves holding information and mentally processing it (Diamond 2013). In order to understand how an individual reacts to pressure it is necessary to consider a range of coping related variables located in different domains, such as physiological variables, personality traits and psychological states. Therefore, the aim of this study was to understand how working memory relates to coping related variables under various pressure conditions.

2.1.1. Working memory

Working memory has been directly linked to many important cognitive processes such as reasoning and problem solving (Just and Carpenter 1992). Working memory has been shown to influence multiple aspects that are important for sports performance including choking under pressure, skill acquisition, skill execution and attention (Furley and Memmert 2010) therefore its investigation within athletic samples is of interest. There are two key theories that are associated with working memory and its influence on performance breakdown under pressure. The first is related to worries and ruminations which "blocks up" the capacity to use working memory (Beilock and Carr 2005). The second supports the notion that consciously controlling a skill loads working memory and prevents smooth executions of skills (Masters and Maxwell 2008). Both of these theories support the concept that working memory capacity is directly linked to the ability to perform under pressure (Masters and Maxwell 2008; Beilock and Carr 2005). When specifically assessing working memory performance it is important to differentiate the degree of pressure. Greater impairments of working memory performance have been found under high pressure conditions when compared to low pressure conditions (Laborde et al. 2015a). Previous research has investigated variables associated with working memory performance under pressure to help understand successful performance, one being the physiological underpinning of working memory.

2.1.2. Physiological basis of working memory

The physiological underpinning of working memory performance under pressure has been linked to cardiac vagal activity (Thayer et al. 2009). The link between working memory and cardiac vagal activity can be explained from a theoretical perspective by the neurovisceral integration model, which suggests that higher cardiac vagal activity is associated to better executive functioning (Thayer et al. 2009), in this case working memory. This relationship is theorised to exist because cardiac vagal activity can reflect the integrity of functioning of the pre-frontal cortex (Thayer et al. 2009). Previous research has found positive associations between executive function and cardiac vagal activity both resting and task (Laborde and Raab 2013; Laborde et al. 2014a; Laborde et al. 2015a), which demonstrates the importance of assessing cardiac vagal activity at different tonic points. Therefore, from the previous research knowledge it is predicted that higher levels of resting and task cardiac vagal activity will be positively associated to working memory performance. Interestingly Laborde and colleagues (2015) found a relationship between resting cardiac vagal activity and working memory performance, but not task cardiac vagal activity. However, they only accounted for tonic cardiac vagal activity measurements and not phasic measures (the change in cardiac vagal activity across tonic time points). Measuring phasic cardiac vagal activity is important to consider in order to understand adaptation processes. If the task involves executive functioning, a smaller decrease in cardiac vagal reactivity (reduction from resting to task) is seen to be adaptive (Thayer et al. 2012). Therefore, it is predicted that a smaller cardiac vagal reactivity (less of a reduction from resting to task) will be positively associated to working memory performance. Although there is good evidence to suggest a link between the physiological functioning of an individual and working memory performance, there have been limited studies that have examined this physiological model in relation to other subjective coping related variables, in particular to personality variables.

2.1.3. Working memory and trait coping related variables

Traits have been found to influence cognitive performance under pressure and specifically this relationship has been explored between working memory and reinvestment (Laborde et al. 2015a). Reinvestment is an overarching term that triggers individuals to consciously control performance under pressure through cognitive effort, which can result in decreased performance (Laborde et al. 2014a; Poolton et al. 2011; Kinrade, Jackson and Ashford 2010). Reinvestment can be split into movement and decision dimensions. Movement reinvestment is “the manipulation of conscious, explicit, rule based knowledge, by working memory, to control the mechanics of one's movements during motor output” (Masters and Maxwell 2004, p. 208). Those higher in movement reinvestment perform worse under pressure (Mullen et al. 2007; Mullen et al. 2005; Chell et al. 2003; Hardy et al. 2001). Decision reinvestment is defined as overthinking, through consciously controlling thoughts and/or ruminative thoughts, which is caused by investigating high levels of cognitive effort that negatively affects performance (Kinrade et al. 2010). It has been shown that those individuals higher in this type of reinvestment tend to score lower on working memory tasks when placed under pressure, for example highly complex modular arithmetic tasks (Kinrade et al. 2010) and the automated version of the operation span task (Laborde et al. 2015a). Only two studies have examined the link between the reinvestment traits and cardiac vagal activity (Laborde et al. 2014a; Laborde et al. 2015a). The first examined decision reinvestment, cardiac vagal activity and decision making under pressure (Laborde et al. 2014a). Results showed that those higher in decision reinvestment took longer to make a decision in high pressure condition, which may be linked to the conscious monitoring of thoughts slowing the decision process (Kinrade et al. 2010). In addition, cardiac vagal reactivity was higher (a larger decrease from resting to task) in the high pressure condition for high reinvestors (Laborde et al. 2014a), which may have led to a less effective cognitive functioning during the task

(Thayer et al. 2009). The second study examined both decision and movement reinvestment together with cardiac vagal activity regarding their relationship with working memory performance (Laborde et al. 2015a). They found that high levels of decision reinvestment and resting cardiac vagal activity were negatively related to working memory performance. Moreover, cardiac vagal activity predicted working memory performance over and above reinvestment (Laborde et al. 2015a). Therefore, the prediction for the current study is that decision reinvestment will be negatively related to working memory performance under pressure.

Another trait of interest is trait emotional intelligence, which is defined as a constellation of emotional self-perceptions situated at the lower levels of personality hierarchies (Petrides et al. 2007). Although trait emotional intelligence has yet to be explored within working memory performance, it has been shown to benefit cognitive performance (Sanchez-Ruiz et al. 2013; Laborde et al. 2010), through its positive role in emotion regulation. A recent review of EI and cognitive processing highlighted the fact that more work should be done to understand the role of EI in specific cognitive tasks (Gutierrez-Cobo et al. 2016). Previous studies have shown that trait emotional intelligence positively influences levels of cardiac vagal activity under stress (Laborde et al. 2015b; Laborde et al. 2011). Specifically, higher trait emotional intelligence has been associated to higher levels of tonic cardiac vagal activity both at rest (Laborde et al. 2015b) and during stress (Laborde et al. 2011). This may suggest that trait emotional intelligence may have indirect effects on working memory performance through its influence on cardiac vagal activity. Therefore, it is predicted that trait emotional intelligence is associated to higher levels of resting and task cardiac vagal activity.

2.1.4. Working memory and state coping related variables

In addition to trait variables, it is also important to understand the subjective state psychological components involved with coping related variables. Specifically, the focus here is on challenge and threat appraisals, which have been shown to play a role within cognitive performance under pressure. Challenge and threat appraisals allow for an understanding of demand and resource evaluations within a pressurised environment (Tomaka et al. 1993) and have been examined with cognitive performance under pressure such as the Stroop task (Turner et al. 2012). In addition, those who displayed threatened patterns were found to have a decrease in cardiac vagal activity under pressure (Laborde et al. 2015b). Given the predictions of the neurovisceral integration model, this drop in cardiac vagal activity may negatively affect cognitive performance that involves executive functioning (Thayer et al. 2009). Therefore, it can be predicted that threat appraisals will have a negative influence on cardiac vagal activity. With regard to attention and working memory performance, one study examined the relationship between attention, working memory and cardiac vagal activity (Hansen et al. 2003). It was found that those higher in cardiac vagal activity were better able to sustain their attention across the task when compared to those with lower cardiac vagal activity (Hansen et al. 2003). The same pattern was found for working memory scores in the study, which suggests working memory and attentional processes are directly linked and benefit from higher levels of cardiac vagal activity. Although attention direct was not measured it could be suggested that those who have attention directed towards the working memory task will perform better.

2.1.5. Study one aims and hypotheses

It has been illustrated that cardiac vagal activity is influenced by coping related variables under pressure (Laborde et al. 2015a; Laborde et al. 2015b; Laborde et al 2014). In addition, working memory performance may be influenced directly by cardiac vagal activity (Laborde et al. 2015a; Thayer et al. 2009) or indirectly through coping related variables under pressure (Laborde et al. 2015a; Laborde et al. 2015b). However, the coping related variables of interest have mainly been studied in isolation and this hinders the comprehension of the psychophysiological components needed to cognitively perform under pressure. By systematically assessing these variables new knowledge can be developed around which variables hold the most influence over psychophysiological reactions and which help or hinder cognitive performance. This study aims to:

1) Investigate the influence of coping related variables on the cardiac vagal activity throughout a pressurised event.
2) Assess the role of coping related variables (including cardiac vagal activity) on working memory performance.

In this study working memory will be assessed under low and high pressure conditions and examined in conjunction with cardiac vagal activity, reinvestment, trait emotional intelligence and challenge and threat appraisals. Based on the reviewed literature it is possible to make the following broad predictions: cardiac vagal activity will be influenced by coping related variables throughout the pressurised task and working memory performance will be influenced by both cardiac vagal activity and coping related variables. A specific breakdown of hypotheses for study one are listed as follows:

- H1) Resting and task cardiac vagal activity will be positively influenced by trait emotional intelligence, specifically emotionality, across pressure conditions.
- H2) Resting cardiac vagal activity will be positively related to task and post-task cardiac vagal activity and tonic post-task cardiac vagal activity will be positively related to task cardiac vagal activity.
- H3) Resting tonic cardiac vagal activity may predict phasic cardiac vagal activity across pressure conditions.
- H4) Higher resting cardiac vagal activity and lower scores in decision reinvestment will have a positive influence on working memory performance in the high pressure condition.

- H5) A smaller decrease in cardiac vagal reactivity will be positively associated to working memory performance in the high pressure condition.
- H6) Threat appraisals will decrease cardiac vagal reactivity in the high pressure condition.

2.2. Methods

2.2.1. Participants

Forty-nine participants (Female = 28, Male = 21, M_{age}=24.1, SD=6.5) took part in the experiment. Purposive sampling was used and participants were recruited through posters around the university site, this can be seen in appendix two. A priori sample size estimations were carried out in line with the following settings: power (1-β error probability) was set to 0.8 which is recommended by (Cohen 1992), statistical significance (α-level) was set to .05 as this is typically used within psychology (Field 2009) and effect size set to R^2 = .30 which has been found for significant relationships within similar research (i.e. Laborde et al 2015a; Laborde et al 2015b; Turner et al 2013). The sample size estimate was between 54-79 (all calculations can be seen in appendix five). All participants were athletes currently competing in a variety of sports (team = 40, individual = 9) some examples include netball, rugby, football, cricket, tennis and badminton. Participants had an average of 10.7 years' experience (SD=7). Participants were asked if they had a history of cardiac disease or if they were taking any medication which could affect the heart, none reported so.

2.2.2. Research design

The study used a within subject design. Within subject designs are recommended in heart rate variability research as it allows for optimal experimental control, reduces individual differences in respiratory rate, requires fewer participants and reduces the impact of external variables such as sleep (Quintana et al. 2014). Within subject design can promote learning effects of a task and habituation of conditions may occur (Laborde et al. 2017), however, these confounding effects were reduced by implementing counterbalanced conditions (Laborde et al. 2014a). Participants performed in the same task across two different pressure conditions, low and high, approximately within one week of each other which were counterbalanced.

2.2.3. Measures

Personality measures. The Trait Emotional Intelligence Questionnaire (TEIQue) (Petrides and Furnham 2003) measures emotional intelligence as a trait. It measures four main factors: well-being, self-control, emotionality and sociability and has 15 subscales. It has 153 items which are scored on a seven-point Likert-scale from 1 (completely disagree) to 7 (completely agree) (Petrides and Furnham 2003). Some samples of items include “I would describe myself as a calm person” and “I often find it difficult to recognise what emotions I’m feeling”. It was deemed a reliable scale in the current study (global score α=.74, wellbeing α=.87, self-control α= 91, emotionality α=.89, sociability α=.86).

The Movement-Specific Reinvestment Scale (MSRS) was used (Masters and Maxwell 2008). The MSRS is a nine item scale which has two internal sub-scales, conscious motor processing and movement self-consciousness. Items are rated on a five point Likert scale which ranges from 1 strongly agree to 6 strongly agree and some sample items include “I am always trying to think about my movements when I carry them out”. The MSRS was deemed reliable in the current study (α=.83).

The Decision-Specific Reinvestment Scale (DSRS) by Kinrade, Jackson, Ashford and Bishop (2010) consists of 13 items, which was reliable in the current study (α=.84). It is rated on a five point Likert scale ranging from 0 not characteristic to 4 very characteristic. An example item includes "When I am reminded about poor decisions I have made in the past, I feel as if they are happening all over again".

Cardiac vagal activity. Heart rate variability, from which cardiac vagal activity is derived, was measured using the eMotion Faros 180° (Mega Electronics Ltd, Pioneerinkatu, Finland) which collects electrocardiogram (ECG) data from two electrodes. Sampling rate was set to 500hz as this is deemed to be a conservative sampling rate (Laborde et al. 2017; Bernston et al. 2007). The first electrode was placed in the right infraclavicular fossa and the second electrode was aligned with the left 12th rib. Disposable ECG pre-gelled electrodes were used (Ambu VLC-00-S/25, Ambu GmbH, Bad Nauheim, Germany).

Perceived stress intensity. A visual analogue scale (VAS) was used to in order to rate stress intensity. Participants were asked how stressed they felt at the present moment and placed a cross on a 100mm line, anchored from "not at all stressed" to "extremely stressed" (Lesage et al. 2012).

Perceived pressure. The pressure/tension subscales were utilised from the intrinsic motivation inventory (Ryan 1982). This consisted of four items including statements like "I felt tense while doing the task" and "I was anxious while doing the task" which were subsequently rated on a Likert scale ranging from 1 (strongly disagree) to 7 (strongly agree).

Attention. The original suggestion by Tammen (1996) only had one single item to rate from 0 *(attention away from task and body)* to 10 *(attention on task and body).* However, in previous research the suggestion to specify two scales where the attention was directed, either task or self, has been noted (Laborde et al. 2015b). Therefore, two separate VAS scales were used in order to differentiate from the task and the self. Participants placed a cross on the line to determine where their attention was focused during the task. The first was anchored by the phrase "towards the task" at the bottom of the line and “away from the task” at the top in order to reflect distraction theory. The second was anchored by the phrases “towards self” at the bottom of the line and “away from self”.

Cognitive appraisal. The cognitive appraisal ratio was adopted to reflect challenge and threat appraisals (Tomaka et al. 1993). The two items are “How demanding did you feel the task was?” which relates to the perceived demand within the situation and “How able were you to cope with the demands of the task?” to assess the perceived resources that are available to the individual in order to cope with the demands faced (Tomaka et al. 1993; Lazarus 2000). Participants rated the items on a six point Likert scale anchored from 1 (not at all) and 6 (extremely).

Motivation and effort. Participants completed a single item indicating “How motivated were you to perform to your best in this task?” on a six point likert scale from 0 (not at all) to 5 (very much so).

Working memory performance. The automated version of the operation span task (AOSPAN), which measures working memory, was used in this study (Unsworth, Heitz, Schrock and Engle 2005; Turner and Engle 1989). This task has been proven to be sensitive to pressure manipulations (Leach and Griffen 2008) and has been used in conjunction with personality traits, specifically reinvestment and cardiac vagal activity (Laborde et al. 2015a). The task involved participants solving maths problems and remembering orders of letters. A typical sequence would consist of a maths question such as (4*5) – 5 = ?, followed by an answer which the participant selected true or false, followed by a single letter such as P. Once the sequence was complete the participant had to recall the letters in the order they appeared. The task consists of 15 separate trials which varied in size of three sets of maths and letters to seven sets, which were randomised. In total there were 75 letters and 75 maths problems presented. If participants took too long over the trial it was counted as an error, the time allowed to answer the question was their average answer time plus 2.5 standard deviations (Unsworth et al. 2005). Figure 5 displays an example problem that the participant was faced with under pressurised conditions.

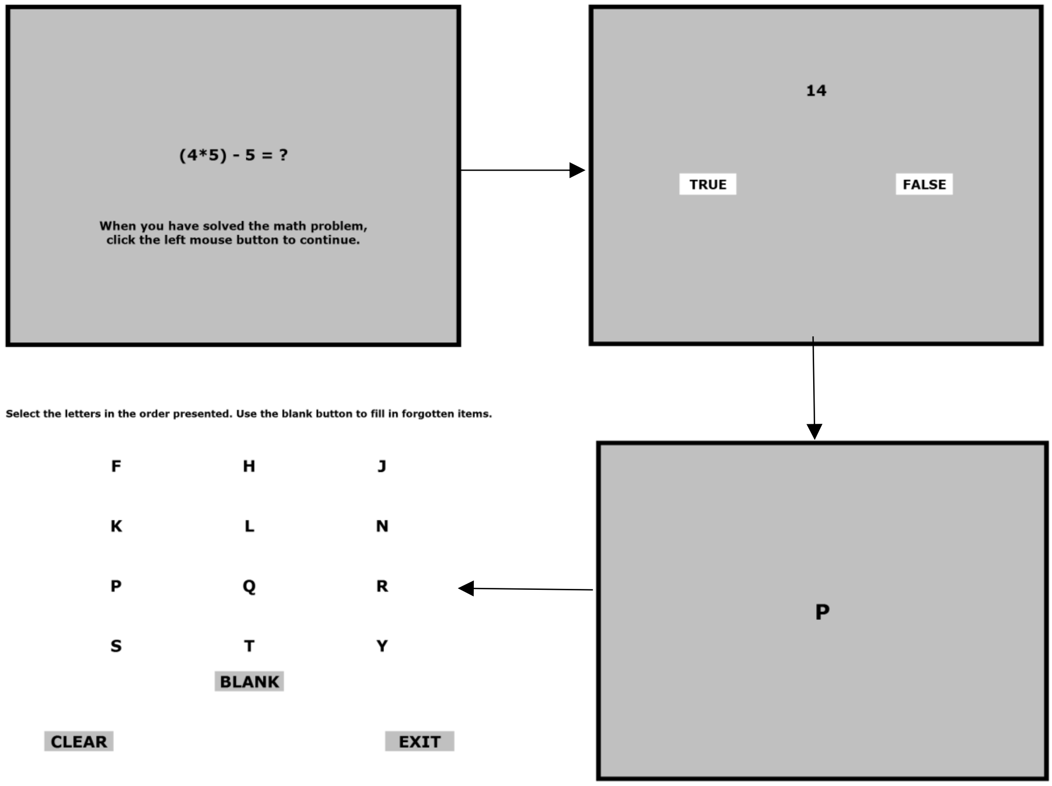

Figure 5 The AOSPAN task (Adapted from Unsworth et al. 2005)

2.2.4. Procedures

Pre-performance procedures. Ethical approval was granted from the University ethics board. Recruitment was conducted through the use of advertisements (see appendix two) placed around the university site which were aimed at individuals actively competing in sport. Once recruited, participants were given an information sheet, provided written informed consent and were emailed the battery of online questionnaires (which include the TEIQue, MSRS, DSRS). After the participants completed the questionnaires they were invited to the first lab session and asked to refrain from heavy exercise 24 hours before attending and avoid consuming caffeine and food two hours before the session.

When participants arrived at the laboratory they were prompted to re-read the information sheet, which was followed by the attachment of two electrodes and the Faros 180° device which was then activated to begin recording. Participants were then seated, arms in lap, palms upwards and eyes closed (Laborde et al. 2017) and a resting heart rate variability reading was taken for five minutes, after which the first stress VAS was completed.

Performance. Before beginning the AOSPAN test the participants listened to a pre-recorded high or low pressure script, developed in line with Baumeister's (1984) recommendations. In the low pressure condition, the script detailed the stipulations of the task which was coined as a memory competition (see appendix one for script and pressure manipulation table). The top five performers would receive monetary incentives (£50, £25, £15, £10, £5) and the worst five performers would be interviewed and a public leader board of results emailed to all participants. In addition to the script, the high pressure condition used further pressure manipulations which were imposed through the participants being filmed and the implementation of performance comparison with national databases. To further induce pressure a second experimenter actively made notes on "behavioural reactions" throughout the task, ensuring to make noise and move around the participant whilst doing the task. Furthermore, the percentage of maths success was shown in the corner of the screen. Participants were told that their current score was below the mean generally achieved by a similar population, which mirrored the procedure used in Laborde et al. (2015a).

The participant then commenced the AOSPAN task and followed the on screen instructions for the practice trials. After the practice trials the participant was reminded of the competitive instructions and started the competitive trial. In total the AOSPAN task lasted approximately 15 minutes from which the last five minutes were used as the heart rate variability recording. The last five minutes of the task were recorded as "task heart rate variability" as the recordings need to be the same length in order to compare data (Bernston et al. 1997). Taking the last five minutes of the task rather than the first five minutes allows the researcher to include the effects of pressure in HRV calculation and this mirrors procedures used in previous research (Laborde et al. 2015a; Laborde et al. 2015b; Laborde and Raab 2013).

Directly after the end of the task, the participant completed the second VAS and remained seated for a further five minutes while post task heart rate variability was recorded. Lastly, the final set of subjective measures was taken including the third stress VAS, attention VAS, cognitive appraisal ratio, pressure/tension scale and motivation item. The participants were thanked, debriefed and notified about their second visit to the lab which was within a week of the first visit, which is in accordance with similar research in this area (Laborde et al. 2015a). A detailed version of the procedural outline can be seen in Figure 6.

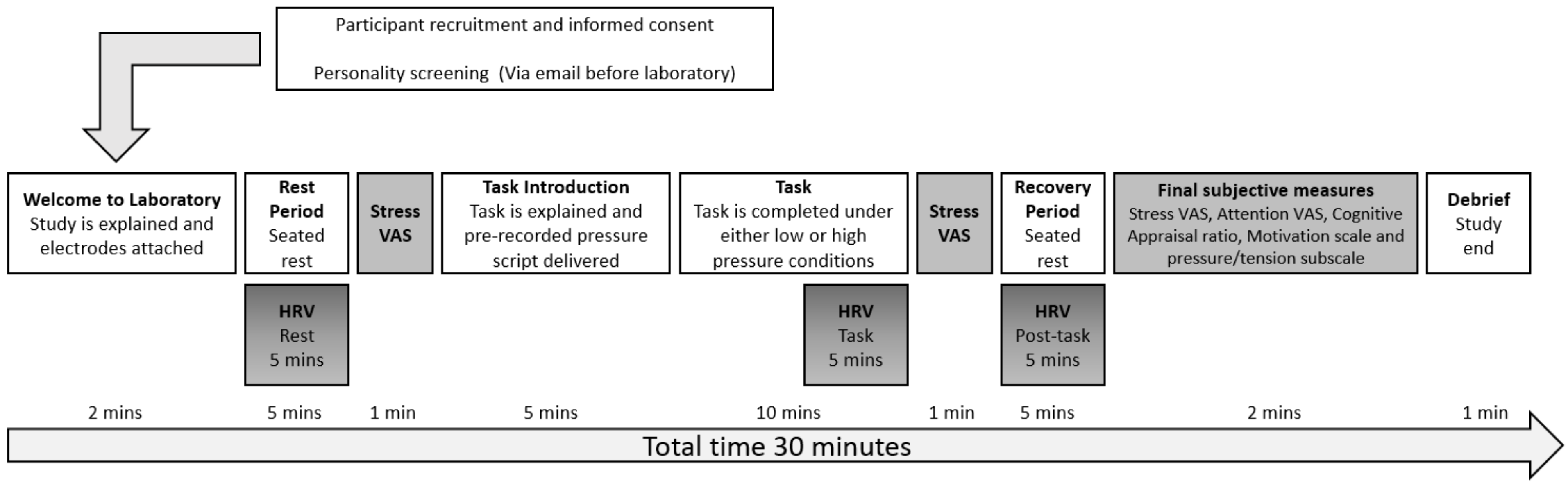

Figure 6 Study procedure

Firstly, the challenge and threat ratio was determined by dividing demands from resources (Tomaka et al. 1993) and all personality questionnaires were coded and scored accordingly. Secondly, HRV data were processed for artefacts, which was done through Kubios (Tarvainen et al. 2014). Artefact correction no higher than low threshold (1%) and data was visually inspected to ensure artefacts were correctly being identified (Laborde et al. 2017). Next, indicators of cardiac vagal activity were extracted, in this study high frequency absolute power derived from the Fast Fourier Transform was used, which is deemed a reliable measure for cardiac vagal activity (Malliani et al. 1994). Thirdly, data were first checked visually for normality via histograms and boxplots. If any outliers existed, they were winzorized (mean + 2x standard deviations). HRV variables were not normally distributed, therefore a log10 transform was applied. This was completed in order to better approximate a normal distribution and to conform parametric assumptions from the data (Quintana et al. 2013) and is in line with procedures used in other research of this nature (Park et al. 2014). After data transformation, the data was checked again for normality and it was ensured they had a z score of between ±2.58 (Field 2009), all variables were considered to be normally distributed.

2.2.6. Data analysis

To ascertain whether the pressure conditions were successful, a repeated-measures MANOVA was used with condition (low pressure vs. high pressure) set as the within subject factor and the subjective stress variables (Stress VAS after the task, pressure and tension subscales) as dependent variables. A pressure effect would be noted by higher ratings of stress after the task, higher ratings of subjective pressure and lower ratings of relaxation in the high pressure condition when compared to the low pressure condition. To explore the contribution of coping related variables to cardiac vagal activity (resting, task, post task, reactivity and recovery) bivariate correlations were run followed by hierarchical stepwise linear regression analyses. Using a hierarchical regression the predictors for cardiac vagal activity 1) resting, task, post task, reactivity, and recovery cardiac vagal activity and 2) working memory performance, were entered as dependent variables. The first block included age and gender, which allowed the researchers to control covariates that may affect heart rate variability data. The second block was used to explore the contribution of coping related variables (reinvestment, trait emotional intelligence, challenge and threat ratio, cardiac vagal activity) to cardiac vagal activity and the contribution of the coping related variables and cardiac vagal activity to working memory performance under pressure. When assessing any phasic variables, or when phasic variables were used as a predictor, resting cardiac vagal activity was also controlled for in the first block of the hierarchical regression.

Preliminary checks. In order to ensure all participants were motivated to compete in both conditions, a one item measure asked "How motivated were you to perform to your best in this task?" on a six point Likert scale from 0 (not at all) to 5 (very much so). The participants appeared to be motivated in both the low pressure condition (M=4.11, SD=0.79) and the high pressure condition (M=4.15, SD=0.94). A paired sample t-test confirmed there was no difference between motivation in both conditions $t(47)=-1.550$, $p=.128$, $d = -0.22$. Breathing rate was also checked across conditions, this was to ensure participants did not change their breathing patterns across conditions. There should be no differences in respiratory frequency between experimental tasks when drawing conclusions from cardiac vagal activity (Laborde et al. 2017). To do this a measure of estimated respiratory frequency, derived from the electrocardiogram derived respiration variable obtained post-hoc from Kubios (Tarvainen et al. 2014), was compared across both low and high pressure conditions. A paired sample t-test confirmed there was no difference between breathing rate in both conditions $t(48)=.497$, $p=.622$, $d = 0.070$.

2.3. Results

Descriptive data are reported in Table 2 and a correlation matrix featuring all study variables can be found in Tables 3 and 4.

Table 2 Descriptive statistics for study one

	M	SD		
Age	24.12	6.57		
Trait Variables				
DSRS	26.89	9.74		
MSRS	24.06	9.74		
Trait EI - Well-Being	5.23	0.88		
Trait EI - Self-Control	4.44	0.88		
Trait EI - Emotionality	4.81	0.82		
Trait EI - Sociability	4.84	0.73		
Trait EI - Global Score	4.8	0.61		
Performance Variables	*High Pressure Condition*		*Low Pressure Condition*	
	M	SD	M	SD
Working Memory Score	37.06	13.78	44.51	18.13
Attention Towards Task	12.75	19.57	10.93	15.28
Attention Towards Self	59.79	31.48	48.55	36.22
Perceived Demands	4.55	1.24	4.36	1.16
Perceived Resources	4.02	1.01	4.40	0.88
Demand/Resource Ratio	-.53	1.89	0.12	1.82
Resting CVA	2.94	0.42	2.89	0.30
Task CVA	2.66	0.34	2.69	0.39
Post Task CVA	2.96	0.41	2.95	0.36
Reactivity CVA	-.15	0.28	-.19	0.32
Recovery CVA	1.76	0.48	.25	0.38
Perceived Stress Post Rest	12.81	11.94	9.87	8.82
Perceived Stress Post Task	48.12	25.59	32.36	23.17
Perceived Stress Post Recovery	23.14	17.68	16.18	15.80
Perceived Tension Post Task	5.22	1.61	4.20	1.81
Perceived Pressure Post Task	5.20	1.80	4.04	1.95
Perceived Anxiety Post Task	4.46	1.65	3.57	1.67
Perceived Relaxation Post Task	2.69	1.58	3.79	1.80
Motivation to Compete	4.34	0.77	4.47	0.61

Note: DSRS = Decision reinvestment total score; MSRS = Movement reinvestment total score; Trait EI = Trait Emotional Intelligence; CVA = Cardiac Vagal Activity (indexed by high frequency HRV absolute power – log transformed)

Table 3 Correlation matrix for all variables (Low Pressure Condition, study one)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1. DSRS	-														
2. MSRS	.61**	-													
3. Trait EI - Well-Being	-.37**	-.42**	-												
4. Trait EI - Self-Control	-.21	-.57**	.48**	-											
5. Trait EI - Emotionality	-.52**	-.48**	.69**	.45**	-										
6. Trait EI - Sociability	-.27	-.19	.51**	.18	.54**	-									
7. Trait EI - Global Score	-.46**	-.56**	.85**	.70**	.87**	.65**	-								
8. Attention Towards Task	.24	.21	.03	-.08	-.03	.01	-.04	-							
9. Attention Towards Self	.16	.15	-.18	-.32*	-.12	-.06	-.24	-.17	-						
10. Demand/Resource Ratio	-.04	-.41**	.16	.54**	.23	.13	.37**	-.06	-.14	-					
11. Resting CVA	.21	.12	-.08	-.05	-.17	-.12	-.15	.06	.01	-.04	-				
12. Task CVA	.36**	.22	-.18	-.00	-.33*	-.13	-.21	-.03	.02	.04	.61**	-			
13. Post Task CVA	.02	.09	-.04	-.05	-.03	-.09	-.07	.14	-.12	-.08	.55**	.47**	-		
14. Reactivity CVA	.25	.16	-.14	.04	-.25	-.05	-.12	-.10	.01	.10	-.21	.64**	.05	-	
15. Recovery CVA	-.35*	-.13	.14	-.05	.30*	.05	.15	.16	-.14	-.12	-.09	-.56**	-.45**	-.60**	-
16. Working Memory Score	.14	.22	-.06	-.06	-.24	-.03	-.16	.02	.10	-.06	.01	.11	-.06	.13	-.18

**p* < .05*;* ***p* < .01

Note: DSRS = Decision reinvestment total score; MSRS = Movement reinvestment total score; Trait EI = Trait Emotional Intelligence; CVA = Cardiac Vagal Activity

Table 4 Correlation matrix for all variables (High Pressure Condition, study one)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1. DSRS	-														
2. MSRS	.61**	-													
3. Trait EI - Well-Being	-.37**	-.42**	-												
4. Trait EI - Self-Control	-.21	-.57**	.48**	-											
5. Trait EI - Emotionality	-.52**	-.48**	.69**	.45**	-										
6. Trait EI - Sociability	-.27	-.19	.51**	.18	.54**	-									
7. Trait EI - Global Score	-.46**	-.56**	.85**	.70**	.87**	.65**	-								
8. Attention Towards Task	.01	.04	.09	-.02	.00	-.02	.02	-							
9. Attention Towards Self	.12	.04	-.17	-.19	-.01	.05	-.12	.05	-						
10. Demand/Resource Ratio	.11	-.18	.19	.52**	.12	.01	.27	-.08	-.18	-					
11. Resting CVA	-.24	-.00	-.11	-.22	-.00	.01	-.11	.07	.08	-.15	-				
12. Task CVA	-.09	.04	-.03	-.17	.10	.07	-.02	-.27	.00	-.12	.59**	-			
13. Post Task CVA	-.08	.06	.07	-.19	.06	.19	.03	.039	.02	.04	.57**	.37**	-		
14. Reactivity CVA	.19	.02	.06	-.19	.00	.27	-.27	-.10	.11	.03	-.24	.21	-.12	-	
15. Recovery CVA	-.11	.06	.54	-.10	.05	.15	.04	.16	.09	-.00	.31*	-.07	.80**	-.37**	-
16. Working Memory Score	-.04	.13	-.03	-.08	-.03	-.01	-.06	.18	-.15	.04	-.17	-.40**	-.07	-.08	.05

*p < .05; **p < .01

Note: DSRS = Decision reinvestment total score; MSRS = Movement reinvestment total score; Trait EI = Trait Emotional Intelligence; CVA = Cardiac Vagal Activity

2.3.1. Pressure manipulation checks

The MANOVA showed a significant main effect for condition, Wilks' Lambda =.66, F(3, 46) =7.69 , p <.001, η^2=.33. Follow up ANOVA's showed a main effect for stress rating after the task with a significant increase in stress following the high pressure condition when compared to low pressure condition F(3,46) = 19.77, p<.001, η^2 = .29, this was also found for pressure ratings F(3,46) = 15.7, p<.001, η^2 = 0.24. A main effect for feelings of relaxation was also found with a significant decrease in relaxation when competing in the high pressure condition when compared to the low pressure condition F(3,46) = 13.57, p=.001, η^2 = .22. Results indicate that the pressure manipulations were successful in creating low and high pressure conditions.

2.3.2. Coping-related variables influence on cardiac vagal activity in low pressure

Correlations between all variables are reported in Tables 3 and 4. As study variables were intercorrelated a series of stepwise regressions were performed to identify salient predictors (Table 5). There were no predictors for resting cardiac vagal activity. For task cardiac vagal activity the first predictor extracted was the level of resting cardiac vagal activity (adjusted R^2 = 0.37, p < .001). The second predictor extracted was DSRS (adjusted R^2 = 0.06, p < .001). The two predictors together accounted for 43% of the variance in task vagal activity. For post task the first and only predictor extracted was the level of resting cardiac vagal activity (adjusted R^2 = 0.29, p < .001). For cardiac vagal reactivity, there were no predictors. For cardiac vagal recovery, the first and only predictor extracted was decision reinvestment (adjusted R^2 = 0.10, p = .014).

Table 5 Multiple (stepwise) regressions for cardiac vagal activity (Low pressure condition, study one)

Model	Unstandardized coefficients		Standardized coefficients	*t*
	B	Std Error	β	
Task CVA				
1 Resting CVA	.78	.14	.61	5.27**
2 Resting CVA	.71	.14	.55	4.90**
DSRS	.01	.00	.25	2.20**
Post Task CVA				
1 Resting CVA	.65	.14	.55	4.57**
Recovery CVA				
1 DSRS	.-.01	.00	-.35	2.56*

***$p < .05$; **$p < .01$**

Note: CVA = Cardiac Vagal Activity, DSRS = Decision reinvestment score
If regressions had no predictors they were excluded from the table.

2.3.3. Coping related variables influence on cardiac vagal activity in high pressure

Correlations between all variables are reported in Tables 3 and 4. As study variables were intercorrelated a series of stepwise regressions were performed to identify salient predictors (Table 6). Each regression specifies the predictor variables that were entered at each point. For resting cardiac vagal activity all trait psychological variables were entered and no predictors were found. For task cardiac vagal activity all trait, state psychological variables and resting cardiac vagal activity were entered at this stage. The first and only predictor extracted was the level of resting cardiac vagal activity (adjusted $R^2 = 0.34$, $p < .001$). For post task cardiac vagal activity trait, state psychological variables and resting and task cardiac vagal activity variables were entered. The first and only predictor extracted was resting cardiac vagal activity (adjusted $R^2 = 0.34$, $p < .001$). For cardiac vagal reactivity, trait and state psychological variables were entered at this stage and resting cardiac vagal activity. No predictors were found. For cardiac vagal recovery, trait and state psychological variables and resting cardiac vagal activity were entered at this stage. The first (and only) predictor extracted for cardiac vagal recovery was resting cardiac vagal activity (adjusted $R^2 = 0.08$, $p = .028$).

Table 6 Multiple (stepwise) regressions for cardiac vagal activity (High pressure condition, study one)

Model	Unstandardized coefficients		Standardized coefficients	*t*
	B	Std Error	β	
Task CVA				
1 Resting CVA	.49	.09	.59	5.11**
Post Task CVA				
1 Resting CVA	.56	.11	.57	4.82**
Recovery CVA				
1 Resting CVA	.36	.15	.31	2.27*
Working Memory				
1 Task CVA	-15.84	5.28	-.40	-2.99*

***p* < .05; ***p* < .01**
Note: CVA = Cardiac Vagal Activity
If regressions had no predictors they were excluded from the table.

2.3.4. Working memory performance

For performance prediction all trait, state psychological variables and cardiac vagal activity variables were entered at this stage. There were no predictors found for working memory performance for the low pressure condition. In the high pressure condition working memory performance was predicted by task cardiac vagal activity (adjusted R^2 = 0.14, p = .004).

2.4. Discussion

The aim of study one was to assess the predictive role of coping related variables (trait emotional intelligence, reinvestment challenge, appraisals, cardiac vagal activity and attention) on levels of cardiac vagal activity and working memory performance under low and high pressure conditions. Firstly, the predictors of cardiac vagal activity will be discussed and secondly the predictors for working memory performance.

2.4.1. Resting cardiac vagal activity

Hypothesis one predicted that trait emotional intelligence would be positively associated with resting cardiac vagal activity was not supported. In both low pressure and high pressure conditions trait emotional intelligence global score and factors did not emerge as predictors for resting cardiac vagal activity. This prediction was based on previous research where trait emotional intelligence predicted resting cardiac vagal activity, in particular the subscale of wellbeing (Laborde et al. 2015b). However, other research found no association with trait emotional intelligence and resting cardiac vagal activity (Laborde et al. 2011). A methodological reason for variation in findings could be that both of these studies did not use a within subject design, this means that only one measure of baseline was taken. As these studies have only taken a snap shot of cardiac vagal activity over five minutes, this may be why inconsistent findings in the prediction of resting cardiac vagal activity with trait EI emerged. Cardiac vagal activity can be influenced by many transient variables (Laborde et al. 2017), it may be that stable predictors such as traits should either be consistently measured using a within subject design across different conditions or matched to more longitudinal measures of cardiac vagal activity to draw sound conclusions. Therefore, due to the inconsistent results, further investigation is needed into this relationship between trait emotional intelligence and resting cardiac vagal activity.

2.4.2. Task cardiac vagal activity

Hypothesis two suggested resting cardiac vagal activity would predict task cardiac vagal activity was supported. In the low pressure condition, the first predictor of task cardiac vagal activity was resting cardiac vagal activity which replicates the findings from the high pressure condition. Therefore, hypothesis two is further supported, as it was found that higher levels of resting cardiac vagal activity positively influences task cardiac vagal activity across pressure conditions. A second predictor for task cardiac vagal activity was decision reinvestment. Findings suggested that higher levels of decision reinvestment positively influenced cardiac vagal activity during the task. This contradicts hypothesis four and previous findings from Laborde et al. (2014) and Laborde et al. (2015) that showed higher levels of decision reinvestment to be associated to reduced levels of task cardiac vagal activity, potentially due to the role of revisiting decisions made within a task (Kinrade et al. 2010). One important point to note is that this finding was only present within the low pressure condition in the present study and the effects of reinvestment are usually only present within high pressure conditions (Jackson et al. 2006). This could be linked to the principle of trait activation, where individual differences in personality will have a differing impact across different pressure situations (Geukes et al. 2013). For example, it may be that decision reinvestment may have reverse effects in low pressure conditions. Another possible explanation could be that rumination can consist of contemplative and adaptive repetitive thoughts, when the valence associated to those thoughts is positive (Watkins 2008). This can lead to better problem solving, planning and reduces negative moods (Watkins 2008), which may then be associated with an increase in cardiac vagal activity. Although the current finding is unexpected, it may be that more research needs to be conducted into the role of decision reinvestment and cardiac vagal activity in differing pressure conditions.

In the high pressure condition resting cardiac vagal activity was the sole predictor of task cardiac vagal activity. Those who had higher levels of cardiac vagal activity at rest had higher levels of cardiac vagal activity during the task which is supported by previous research (Park et al. 2014). Higher levels of resting cardiac vagal activity have been shown to positively influence adaptive emotional responding (Thayer et al. 2009; Ruiz-Padial et al. 2003) and facilitative behavioural responses during tasks (Hansen et al. 2003). This suggests that individuals with higher resting cardiac vagal activity are better able to meet the demands of the task by regulating themselves in stressful situations. This could be seen to be a benefit for working memory performance as tasks that require executive functioning require higher levels of cardiac vagal activity in order to produce better performance (Thayer et al. 2009).

With regards to hypothesis six, threat appraisals would reduce cardiac vagal reactivity (reduction from resting to task levels), no relationships were found and consequently the hypothesis was rejected. This hypothesis was based on previous research, where threat appraisals were found to be associated to reduced cardiac vagal activity (Laborde et al. 2015b). In the current study , it may be that null findings were discovered as a result of the number of predictors and the shared variance within the analysis. This may also be because cardiac vagal activity does not belong to the traditional cardiac indicators of challenge and threat (Blascovich and Mendes 2000) and therefore may not be consistently linked to cardiac vagal activity.

2.4.3. Post task cardiac vagal activity

Hypothesis two, predicting that resting cardiac vagal activity would positively influence post task cardiac vagal activity was supported. Resting cardiac vagal activity positively influenced the level of post task cardiac vagal activity in both the low and high pressure conditions. Consistent with previous findings resting cardiac vagal activity has shown to have many benefits across health, emotional regulation and stress management (Thayer et al. 2009; Ruiz-Padial et al. 2003; Hansen et al. 2003), the higher the levels of cardiac vagal activity at rest the better able individuals can successfully regulate and adapt during stress. Post task recovery is a crucial indicator of the adaptability of an organism as it determines the ability to effectively return to resting level after facing a stressful event (Stanley et al. 2013). Conversely, lower levels of post task cardiac vagal activity reflects the result of poor self-regulation, as a return to resting level is achieved slower or not at all (Berna et al. 2014). More efficient return to resting levels enables the individual to face another potential stressor, much like the sporting environment where demands can change relentlessly throughout a competition. These findings suggest a higher level of resting cardiac vagal activity fosters more effective cardiac vagal recovery, because a larger cardiac vagal activity is available in the first instance, which allows for a greater uptake of self-regulation resources.

2.4.4. Cardiac vagal recovery

In the low pressure condition decision reinvestment was negatively associated with cardiac vagal recovery, which was not hypothesised. Individuals who were higher in decision reinvestment, had decreased cardiac vagal recovery after the stressful task. This may suggest that the high reinvestors were thinking back to their previous performance even after the task had finished and therefore this prompted a decrease in cardiac vagal recovery. It is not uncommon for those high in this trait to ruminate about past decisions (Kinrade et al., 2010a). Previous research found that high levels of decision reinvestment caused a larger decrease in cardiac vagal activity during a task (Laborde et al., 2014) with large effect (partial η^2 = .19). The current study only found a medium effect (R^2 = .10) and this is a new finding when compared to previous research, as decision reinvestment has not been assessed with cardiac vagal recovery. A point of interest is that the opposing pattern was discovered for task cardiac vagal activity, where those higher in decision reinvestment had higher levels of cardiac vagal activity. It may be that during the task, participants used adaptive repetitive thoughts to solve the task, and after the task the participants then thought back to their performance perhaps in a negative light, which caused a decrease in cardiac vagal activity. This may be an interesting avenue for future research and interventions to help athletes recover more effectively, particularly if the sport contains multiple time points of breaks in play such as tennis.

In the high pressure condition, hypothesis three, assuming that resting cardiac vagal activity would predict phasic cardiac vagal activity, was supported. It was found that higher levels of resting cardiac vagal activity positively influenced the recovery process from task to recovery. This is in line with the notion that higher levels of resting cardiac vagal activity promote cardiac vagal activity enhancement under stress due to an enhanced ability to effectively uptake self-regulatory resources (Park et al., 2015; Park et al., 2014; Segerstrom and Nes, 2007).

2.4.5. Working memory performance

Hypothesis four predicted that resting cardiac vagal activity, lower decision reinvestment and higher resting and task cardiac vagal activity would positively influence working memory performance was not supported. It was also predicted that a smaller decrease in cardiac vagal reactivity would positively influence working memory performance in the high pressure condition (hypothesis five). Hypothesis five was partially supported as findings related to cardiac vagal activity and working memory performance were only present in the high pressure condition, which reflects previous findings (Laborde et al. 2015a). Both study one and the Laborde et al. (2015a) study found medium effects between working memory performance and cardiac vagal activity. Although Laborde's study found resting cardiac vagal activity predicted performance (R^2 = .13) and the current study task cardiac vagal activity was extracted as the predictor (R^2 = .14) In study one there was a negative relationship between working memory performance and levels of task cardiac vagal activity, which would partially support hypothesis four and reject hypothesis five. Lower levels of task cardiac vagal activity positively affected working memory performance. Theoretically this is not supported by the neurovisceral integration model as higher executive functioning performance is associated to high levels of cardiac vagal activity (Thayer and Lane 2000). In previous work higher levels of resting cardiac vagal activity were positively associated to working memory performance (Laborde et al. 2015a; Hansen et al. 2003). However, Hansen and colleagues (2003) found a suppression in RMSSD over the course of the working memory task. This was suggested to be linked to sustained attention, as the duration and intensity of the task increases, and therefore so does the demand on the organism (Porges, 1992). Considering the working memory task was 15 minutes in length and the task cardiac vagal activity measure was derived from the final five minutes, it could be that the negative relationship demonstrates successful adaptation across the time. This may suggest that those who performed better used up their self-regulation resources across the task, resulting in a reduction in cardiac vagal activity at the end of the task. More explorations of the different tonic and phasic measurement points for cardiac vagal activity in combination with different types of working memory tasks and environmental demands are needed to further understand the role of cardiac vagal activity and working memory performance.

2.4.6. Limitations

The limitations of the current study must be acknowledged. Firstly, the nature of the study was laboratory based on a computer task, which can be considered to be quite removed from the sporting environment. Although this isolated cognitive task has limitations, working memory can play an important role in cognitive sporting functions such as reasoning and problem solving (Just and Carpenter 1992). Sample size could have been increased, given other studies of a similar nature had slightly more participants (Laborde et al. 2015b). Another issue with regards to sample is the fact that the sample was heavily biased towards team sports (40) and only had 9 individual sport athletes. This may affect the personality results as team sports showed differences in personality when compared to those who competed in individual sports (Laborde et al. 2016). In future it would be preferable to explore the findings either with purely individual athletes or an equal split between the sporting disciplines.

2.5. Conclusion

To conclude, chapter two detailed study one which aimed to build on previous research that had few and inconsistent combinations of variables across cognitive performance (Laborde et al. 2015a; Laborde et al. 2015b; Laborde et al. 2014a; Park et al. 2013; Park et al. 2012). Therefore study one enhanced knowledge by combining the previous coping related variables that had been examined individually in line with cardiac vagal activity. In addition, study one has developed knowledge around how coping related variables and cardiac vagal activity may be associated to working memory performance under pressure. Specifically, it is demonstrated that resting cardiac vagal activity predicts both task and post task cardiac vagal activity across low and high pressure conditions. This demonstrates that resting levels of cardiac vagal activity play an important role in providing a resource in task and post task for self-regulation under differing pressure demands. There was no association found with other traits that may affect cardiac vagal activity (trait emotional intelligence) and decision reinvestment was the only trait that directly influenced cardiac vagal activity during and after the working memory task. At the theoretical level, we further supported the importance of resting cardiac vagal activity as an enduring resource for self-regulation under differing pressure demands, maintaining the need for its inclusion in pressure research. Decision reinvestment was the only trait that directly influenced cardiac vagal activity during and after the working memory task. We found that decision reinvestment may influence cardiac vagal activity differently across points in experimental tasks. In particular, the role of valence in rumination should be examined (Watkins 2008), in order to determine adaptive and maladaptive patterns associated with decision reinvestment. On this occasion, there was evidence to suggest that higher levels of task cardiac vagal activity were negatively associated with working memory performance. This contradicts previous theory and potentially needs investigating further. At the applied level practitioners need to consider how the levels of decision reinvestment may directly affect an athletes psychophysiological functioning and how to potentially enhance this through understanding rumination in pressurised events. In addition, practitioners may want to consider the possibility of increasing resting levels of cardiac vagal activity, perhaps through slow paced breathing, to foster better physiological recovery from stressors, although this needs further investigation in high pressure conditions.

Finally, the current combination of variables will need further investigation in more ecologically valid settings in order to directly reflect sporting performance. In order to increase ecological validity the introduction of a motor task allows the cognitive and motor demand athletes face when executing skills to be mirrored within a laboratory setting, as these skills are often performed simultaneously (Huang and Mercer 2001). This directly leads into study two in which this limitation will be met.

3. THE CONTRIBUTION OF COPING RELATED VARIABLES AND CARDIAC VAGAL ACTIVITY ON THE PERFORMANCE OF A DART THROWING TASK UNDER PRESSURE

3.1. Introduction

In order to build on the findings from previous literature and study one, study two moves away from isolated cognitive performance and examines the same phenomena within psychomotor performance. Study two aims to bring findings closer to the sporting environment by assessing both physical motor actions and cognitive processes. These processes need to be coordinated effectively in order to produce successful psychomotor performance under pressure (Zillmer et al. 2008). The variables of interest have yet to be examined within this type of task and will go above and beyond the predictions of the neurovisceral integration model, which only provides predictions for cognitive performance (Thayer et al. 2009).

3.1.1. Psychomotor performance under pressure

Pressure can lead to differing levels of physiological arousal (Steptoe and Brydon, 2009) which in turn can influence athletic performance (Laborde et al. 2015b), therefore understanding the effects of pressure on psychophysiological processes and performance is crucial. A variable of current interest is the activity of the parasympathetic nervous system, also refered to as cardiac vagal activity (Shaffer et al. 2014). Cardiac vagal activity can be derived from HRV which is the time interval between heartbeats (Appelhans and Lueken, 2006). Cardiac vagal activity has been considered a measure of adaptation and self-regulation which has been validated through the theoretical work of Thayer, Hansen, Saus-Rose and Johnsen, and their model of Neurovisceral Integration (2009). Cardiac vagal activity has also been combined with other coping related variables such as trait emotional intelligence (Laborde et al. 2011), decision reinvestment (Laborde et al. 2015a) and stress appraisals (Laborde et al. 2015b). This work has shown that coping related variables and cardiac vagal activity influence performance under pressure particularly in cognitive tasks (Laborde et al. 2011; Laborde et al. 2014a; Laborde et al. 2015a; Laborde et al. 2015b). Therefore, in order to form a holistic perspective of performance under pressure, combining variables from different facets of psychology is crucial.

Current research that has combined coping related variables and cardiac vagal activity has only assessed performance involving purely cognitive tasks (Laborde et al. 2015a; Laborde et al. 2014a). This means that current knowledge cannot be directly applied to sporting performance and variables should be examined in line with tasks more related to such performance. In a sporting environment the athlete will often have to perform multiple tasks simultaneously (Huang and Mercer 2001), which tend to involve both physical motor actions and cognitive processes. Psychomotor tasks allow researchers to explore the coordination of sensory or cognitive processes and a motor activity (Zillmer et al. 2008). To test psychomotor performance under pressure, aiming tasks such as golf putting and dart throwing are commonly used. This is because they involve perceptual processes and fine motor movements such as hand-eye coordination (Schmidt and Lee 2014), which can be susceptible to skill breakdown under pressure (Nieuwenhuys and Oudejans 2010; Wilson et al. 2009). Additionally, aiming tasks offer a simple way to assess performance with a clear point system (Nieuwenhuys and Oudejans 2010; Wilson et al. 2009) and in experimental research are often paired with a cognitive element, such as mental arithmetic to increase complexity and stress (Nibbeling et al. 2013; Williams et al. 2002; Murray and Janelle 2003). Psychomotor tasks, therefore, provide a suitable platform for the next phase of the research process. This is an important progression within current research as coping related variables and cardiac vagal activity have seldom been studied together in order to understand contributions to psychomotor performance under pressure. Therefore, study two will build on previous theoretical predictions (Thayer et al. 2009) and extend the findings of study one. Consequently, the aims of this study were 1) to assess the predictive role of coping related variables (trait emotional intelligence, reinvestment, appraisals and attention) on cardiac vagal activity, and 2) investigate the influence of the predictive role of coping related variables and cardiac vagal activity on a dart throwing task under low and high pressure conditions.

3.1.2. Cardiac vagal activity and psychomotor performance

At the psychophysiological level tasks that involve both cognitive process and motor output have been examined in line with cardiac vagal activity. Saus et al. (2012) used a navigation simulator to train naval navigation and perceptual skills in naval cadets, and measured cardiac vagal activity during a training session. They found that whilst individuals were completing the task their cardiac vagal activity (indicated through RMSSD) dropped and the participant's recovery was significantly mediated by their situation awareness scores. Those who had lower situational awareness showed no change in cardiac vagal activity during the task and in recovery. Therefore, this suggests that those individuals who had higher situational awareness were better able to modulate their cardiac activity to meet the external demands of the task, which is an ability controlled by the pre-frontal cortex (Thayer et al. 2015). These findings show the significance of prefrontal functioning, indicated by cardiac vagal activity, in adapting to environmental demands through effective self-regulation (Thayer et al. 2000). This finding also suggests that phasic withdrawal in cardiac vagal activity can be adaptive depending on environmental demands, which was previously theorised by Porges (2007).

Cardiac vagal activity has also been assessed in aiming tasks and findings have suggested that cardiac vagal activity may influence performance outcomes in these tasks. Thompson et al (2015) examined police shooters under pressure and physiological responses to pressure through cardiac vagal activity (as indicated by high frequency (HF) HRV). They found that those participants who had a greater reduction in cardiac vagal activity performed worse and those who displayed a smaller decrease performed better, for example decreases in raw time (the time taken to complete the shooting task). These findings contrast with the Saus et al. (2012) study as a reduction in cardiac vagal activity during the task was seen to be adaptive. This suggests that patterns of phasic cardiac vagal activity are not defined and may differ depending on task demands. One potential explanation for the findings of Thompson et al. (2015) opposing to those of Saus et al. (2012) is that there was significantly more movement involved within the Thompson et al. (2015) shooting task, which may have influenced HRV readings. When excessive movement is involved, the sympathetic system becomes dominant and therefore may overshadow parasympathetic activity readings (Laborde et al. 2017). Therefore, static psychomotor tasks may be more suitable to produce valid findings. Other psychomotor aiming tasks that have been examined in line with cardiac vagal activity involve shooting a basketball through the use of biofeedback (Paul and Garg 2012). Although this study did not directly assess performance under pressure, they did find that slow paced breathing, which increased cardiac vagal activity, improved performance and decreased anxiety. Cooke et al. (2011) assessed expert golf putting under pressure and a number of psychophysiological variables including cardiac vagal activity, although no relationship between performance and cardiac vagal activity was found.

From the evidence presented, it has shown that there are relationships between cardiac vagal activity and psychomotor performance, although results are equivocal at present. Further exploration of cardiac vagal activity with the use of the three R model will allow the current study to assess the psychophysiological changes that occur across a pressurised psychomotor task. It is important to note that cardiac vagal activity is only one variable of interest within the thesis. Thompson and colleagues (2015) do argue that more subjective measures are needed to form a holistic view of the psychophysiological profile of the individual when responding to pressure, which again provides support for combining coping variables. Therefore, this need to build a holistic psychophysiological profile will be addressed within this study.

3.1.3. Coping related variables and psychomotor performance

Cardiac vagal activity has shown an association with other coping related variables and the influence they have on cardiac vagal activity and performance under pressure. Recent research has begun to combine personality traits with cardiac vagal activity in order to examine their effects on performance under pressure (Laborde et al. 2015a; Mosley and Laborde 2015; Laborde et al. 2014a). Two particular traits have been highlighted because of their role during performance under pressure and influence on cardiac vagal activity; trait emotional intelligence and reinvestment. The former represents a constellation of emotional perceptions assessed via questionnaires and rating scales (Petrides et al. 2007). The latter entails two dimensions: movement reinvestment, "the manipulation of conscious, explicit, rule based knowledge, by working memory, to control the mechanics of one's movements during motor output" (Masters and Maxwell 2004, p. 208), and decision reinvestment, which refers to overthinking, through consciously controlling thoughts and/or ruminative thoughts, which is caused by high levels of cognitive effort under pressure that negatively affects performance (Kinrade et al. 2010).

Individuals with higher levels of trait emotional intelligence have been shown to produce superior performance under pressure, through stress buffering effects, in a range of performance settings, such as experimental tasks (learning and decision-making) (Laborde et al. 2010) and sport related tasks (Laborde et al. 2014b). Furthermore, trait emotional intelligence is positively linked to levels of cardiac vagal activity under pressure (Laborde et al. 2011). As trait emotional intelligence was not found to have any links with resting cardiac vagal activity in study one, it will not be tested in study two.

However, as sport related tasks have shown a link between trait emotional intelligence and task cardiac vagal activity (Laborde et al. 2014b), it is predicted that trait emotional intelligence will be positively related to cardiac vagal activity during the task.

Reinvestment, which has two components concerning movement and decision-making can decrease an individual's performance when under pressure (Masters and Maxwell 2004; Kinrade et al. 2010). Higher levels of movement reinvestment have been shown to negatively affect performance (Mullen et al. 2005; Chell et al. 2003). Similar to movement reinvestment, decision reinvestment can also cause performance decrement under pressure (Laborde et al. 2015a; Kinrade et al. 2010). From the psychophysiological perspective, higher levels of decision reinvestment have been found to cause a greater decrease in cardiac vagal activity during a pressurised task (Laborde et al. 2015a; Laborde et al. 2014a), although in one case cardiac vagal activity at rest predicted working memory score above decision reinvestment (Laborde et al. 2015a). Therefore, it is predicted that decision reinvestment will be negatively associated to cardiac vagal activity during the task. Within psychomotor aiming tasks, Weiss (2011) assessed the locus of attention and movement reinvestment in a dart throwing task. Those who scored higher on movement reinvestment and who were asked to non-preferentially focus on external effects of their movement had the worst performance. It was discussed that due to higher levels of movement reinvestment, participants were overwhelmed by the amount of information which resulted in an increase in effortful processing which then affected the motor aspect of performance (Wiess 2011). Therefore, this demonstrates how movement reinvestment may affect psychomotor aiming tasks and it is predicted that higher levels of movement reinvestment will negatively influence dart throwing performance in this study.

State coping related variables have also been shown to link to cardiac vagal activity under pressure. It has been shown athletes who view stressful situations as a challenge tend to perform superiorly to those who view the situation as a threat (Moore et al. 2013). Challenge and threat has been linked to aiming tasks such as netball shooting (Turner et al. 2012) and golf putting (Moore et al. 2012), in which the challenge appraisal was found to promote more facilitative performance. Laborde et al. (2015b) found that when performing a concentration grid task, a greater threat appraisal resulted in a larger decrease in cardiac vagal activity from resting to task. Although cardiac vagal activity is not a traditional indicator for challenge and threat, the predictions of the neurovisceral integration model suggest emotion regulation is connected to parasympathetic activity (Thayer and Lane 2000). Therefore, coping mechanisms, through the appraisal process may affect the levels of cardiac vagal activity during a stressful task (Laborde et al. 2015b).

Within aiming tasks, attentional focus has been found to influence performance. Multiple studies examining dart throwing have found that an external focus towards the dart board (specifically the bull's eye) promoted more accuracy (McKay and Wulf 2012; Marchant et al. 2009; Radlo et al. 2002). This suggests that a task related focus rather than a distraction focus is beneficial for aiming task performance and this pattern of attention has also been explored at the psychophysiological level. Radlo and colleagues (2002) found that when individuals focussed their attention externally towards the dart board, they experience a deceleration in heart rate before the throw, and were subsequently more accurate. A deceleration in heart rate may lead to an increase in cardiac vagal activity, because of the role of the parasympathetic system in slowing heart rate, and there are already proven relationships between cardiac vagal activity and attentional processes (Park et al. 2013; Park et al. 2012; Radlo et al. 2002). Therefore, it is predicted that an attentional focus towards the task will positively influence task performance, which may be influenced by underlying physiological processes.

3.1.4. Study two aims and hypotheses

From the evidence presented it is clear that aiming tasks have a propensity for pressure induction and psychomotor research. A popular aiming task that is commonly used within pressure research as a psychomotor task is dart throwing (Moore et al. 2018; Oudejans et al. 2013; Nibbeling et al. 2013; Williams and Cummings 2012). Dart throwing is an applicable task as it involves the need for attentional regulation and precision when performing under pressure. For example Oudejans and Pijpers (2010) successfully induced low and high anxiety through the use of a dart throwing task at differing heights on a climbing wall. Dart throwing has been used as a dual task which is normally in conjunction with a mental stressor in order increase the amount of pressure that is experienced (Oudejans et al. 2013; Nibbeling et al. 2013). For example Nibbeling and colleagues (2013) created cognitive load through a counting task which involved the participants counting back from a number between 1000 and 500 in increments of three whilst completing a dart throwing task. This task was successful in increasing the amount of perceived mental effort and decreased the response rate of the participants therefore a similar approach will be used in the current study. In addition dart throwing has been assessed with attention, movement reinvestment and heart rate which helps to support predictions for study two.

There is emerging evidence that coping related variables including cardiac vagal activity can play a role in performance under pressure (Laborde et al. 2015a; Laborde et al. 2015b; Laborde et al. 2011). However, the current body of empirical and theoretical knowledge only examines cognitive tasks thus making it difficult to make comparisons to the sporting domain. Moreover, trait and state coping related variables have rarely been considered together concerning their influence on psychomotor performance under pressure.

Therefore, the aims of study two were:

1) Assess the predictive role of coping related variables (trait emotional intelligence and reinvestment, appraisals and attention) on cardiac vagal activity.
2) Investigate the influence of the predictive role of coping related variables and cardiac vagal activity on a dart throwing task under low and high pressure conditions.

Based on previous literature the predictions for study two are presented below:

- H1) Trait emotional intelligence will be positively associated to cardiac vagal activity during the task.
- H2) Tonic cardiac vagal activity at rest will be positively associated to phasic cardiac vagal activity.
- H3) Decision reinvestment will negatively influence cardiac vagal activity during recovery.
- H4) Challenge appraisal will positively affect cardiac vagal activity reactivity.
- H5) Task cardiac vagal activity, attention directed towards the task and challenge appraisal will be positively associated to psychomotor performance.
- H6) Movement reinvestment will negatively influence dart score.

It is important to note that these predictions branch across both low and high pressure conditions. However, the relationships with the coping related variables may be more pronounced under high pressure than low pressure given the stronger role of emotion regulation in this case as seen in other studies assessing differences between low and high pressure conditions (Laborde et al. 2015a; Geukes et al. 2013).

3.2. Methods

The same measures were used as study one and therefore a brief version is reported here.

3.2.1. Participants

Fifty-one participants (30 male and 21 female; M_{age}=24.9, SD=7.7) took part in the experiment. Purposive sampling was used and participants were recruited through posters around the university site, a priori sample size estimations were carried out with power leading to an estimate was between 54-79 (all calculations can be seen in appendix five). All participants competed in a variety of sporting disciplines (team sport=36, individual=15) with an average of 11.7 years' experience (SD=8.3). Participants were asked if they had any cardiac disease or if they were taking any medication that could affect the heart, none reported so. The study was approved by the University ethics committee.

3.2.2. Measures

Personality measures. The Trait Emotional Intelligence Questionnaire (TEIQue) (Petrides 2009) was used and was deemed reliable in the current study; global score α =.81, well-being α =.88, self-control α =.91, emotionality α =.88 and sociability α =.86). The Movement-Specific Reinvestment Scale (MSRS) (original α = .79, current study α = .81) was used and is a nine item scale (Masters and Maxwell 2008). The Decision-Specific Reinvestment Scale (DSRS) by Kinrade, Jackson, Ashford & Bishop, (2010) was used which consists of 13 item measure (original α = .89, current study α = .81).

Cardiac vagal activity. HRV was measured using the Faros 180° device (Mega Electronics Ltd, Pioneerinkatu, Finland). Two pre-lubricated disposable electrodes (Ambu VLC-00-S/25, Ambu GmbH, Bad Nauheim, Germany) were placed on the body, one just below the right clavicle and one on the left side of the chest below the 12^{th} rib.

Perceived stress intensity. A VAS was used to reflect stress intensity on which participants placed a cross on a 100mm line (Lesage et al. 2012).

Attention. A VAS was also used to measure the attentional direction of participants, two separate VAS scales were used in order to differentiate from the task and the self (Laborde et al. 2015b).

Perceived pressure. The pressure/tension subscales were utilised from the intrinsic motivation inventory (Ryan, 1986).

Cognitive appraisal. Challenge and threat appraisals were assessed using the cognitive appraisal ratio (Tomaka et al. 1993). Participants were asked "How demanding did you feel the task was?" and "How able were you to cope with the demands of the task?" and were rated on a six point Likert scale rated from 1 (not at all) and 6 (extremely).

Motivation and effort. Participants completed a single item indicating "How motivated were you to perform to your best in this task?" on a six point Likert scale from 0 (not at all) to 5 (very much so).

Dart throwing experience. Participants were asked about their previous dart throwing experience on a four point Likert scale which ranged from 1 "none at all (I have never thrown a dart)" to 4 "very experienced (I play competitively)", in line with previous research (Cumming et al. 2006).

Dart throwing performance. A Dunlop Sport Tournament size dart board (d= 0.46m) was used with concentric rings of equal size, the outside ring was scored 1 leading to a 12mm red bulls eye in the centre, which scored 10, a miss scored zero. The dart board was positioned at official competition distances (2.37m directly in front of the participants with the bulls eye positioned 1.73m above the participants' feet). Participants received the same set of instructions for basic dart throwing technique to standardize performance (see appendix four). The participants had to gain the best possible reduction from a set total (1234) in five minutes.

Mental stressor task. Participants also had to subtract the dart scores from the set total after each consecutive dart throw and the answers were said out loud. If the answer was correct the participant continued to throw the next dart. However, if a mistake was made in the calculation the participant was notified by the experimenter and the score reverted back to the beginning (1234) and they started again. Furthermore, in the high pressure condition if participants took too long to answer they were prompted to speed up. Mental performance was measured by the number of mistakes made over the five minute time period.

3.2.3. Procedures

Pre-performance procedures. Participants were recruited through advertisements and emails aimed at actively competing athletes. Once recruited, participants read the information sheet, provided written informed consent and completed the battery of online questionnaires (which include the TEIQue, MSRS, DSRS). The participant was then invited to the first lab session. Participants were asked to refrain from heavy exercise 24 hours before attending the lab session and to avoid consuming caffeine and food two hours before the session, as this can affect HRV (Quintana et al. 2013). Participants attended two lab sessions; one in low pressure and one in high pressure, which were counterbalanced. Upon arrival to the practical pressure test participants were prompted to re-read the participant information sheet, after which, individuals had the Faros 180° device attached and activated. Once the participant was comfortable a resting HRV measurement was taken for five minutes. The resting measure was completed in a standing position in order to replicate the experimental task, directly after resting the first stress VAS was completed.

Performance. Before commencing the dart throwing task, participants were given basic instructions on how to throw a dart (see appendix four) and allowed 24 practice shots in order to familiarize themselves with the task. Participants were informed of the competitive rules and the number subtraction task. They then listened to a pre-recorded high or low pressure script which contained pressure manipulations such as being placed on a leader board and gaining monetary incentives for successful performance (see appendix one for script and pressure manipulations). Participants commenced the five minute task under low or high pressure conditions. Specifically, within the high pressure condition additional pressure was added through the participants being filmed, social comparison (scores compared to a professional dart player), and a second experimenter was present who actively made notes on "behavioural reactions" throughout the task. Experimenter behaviour was kept consistent across the testing. Upon task completion participants completed the second stress VAS and a recovery HRV period was completed and recorded. Lastly, the final set of subjective measures were taken including the final stress VAS, pressure VAS, cognitive appraisal ratio, pressure/tension scale and motivation scale. The participants were thanked, debriefed and notified about their second visit to the lab, which was completed within a week of the first task in accordance with similar literature (Laborde et al. 2015a).

3.2.4. Data preparation

Personality scores were coded accordingly and the challenge and threat ratio was determined by dividing demands from resources (Moore et al. 2013). Secondly, heart rate variability data were processed for artefacts, and indicators of cardiac vagal activity were extracted. In this study high frequency absolute power was used, which is deemed a reliable measure for cardiac vagal activity (Laborde et al. 2017). Data were then checked for normality visually via histograms and boxplots. If any outliers existed, they were winzorized (mean + 2x standard deviations). For HRV variables, which were not normally distributed, a log10 transform was applied. After these processes, the data were checked again and was considered to be normally distributed.

3.2.5. Data analysis

To check the dart throwing task was successful in inducing pressure a repeated-measures MANOVA was used with condition (low pressure vs. high pressure) set as the within subject factor and the subjective stress variables stress VAS after the task, pressure and tension subscales) as dependent variables. A pressure task would be evident by higher ratings of stress after the task, higher ratings of pressure and lower ratings of relaxation in high pressure when compared to low pressure. To explore the contribution of coping related variables to cardiac vagal activity (resting, task, post task, reactivity and recovery) bivariate correlations were run followed by hierarchical stepwise linear regression analyses. Using a hierarchical regression the following were entered as dependant variables 1) resting, task, post task, reactivity, and recovery cardiac vagal activity, as well as 2) dart throwing score and math error. When assessing cardiac vagal activity the first block included age and gender, which allowed the researchers to control the covariates of age and gender on HRV measures. When assessing any phasic variables, or when phasic variables were used as a predictor, resting cardiac vagal activity was also controlled for in the first block of the hierarchical regression. The second block was used to explore the contribution of coping related variables (reinvestment, trait emotional intelligence and challenge and threat ratio) to cardiac vagal activity and the contribution of the coping related variables and cardiac vagal activity to shooting performance under pressure.

3.2.6. Preliminary checks

In order to ensure all participants had comparable levels of dart throwing experience a one item measure on a four point Likert scale which ranged from 1 “none at all (I have never thrown a dart)” to 4 “very experienced (I play competitively)” was used. The majority of participants reported some recreational dart throwing experience, only three reported having no experience at all, and no participants playing competitively (*M*=2.02, *SD*=0.37). In addition to check if participants were motivated in the tasks a single item measure was used that asked “How motivated were you to perform to your best in this task?” on a six point Likert scale from 0 (not at all) to 5 (very much so). The participants appeared to be motivated in both the low pressure condition (M=4.11, SD=0.79) and the high pressure condition (M=4.15, SD=0.94). A paired sample t-test confirmed there was no difference between motivation in both conditions $t(50)=.405$, $p=.687$, d = 0.05. Breathing rate was also checked across conditions, this was to ensure participants did not change their breathing patterns across conditions. There should be no differences in respiratory frequency between experimental tasks when drawing conclusions from cardiac vagal activity (Laborde et al. 2017). To do this a measure of estimated respiratory frequency, derived from the electrocardiogram derived respiration variable obtained post-hoc from Kubios (Tarvainen et al. 2014), was compared across both low and high pressure conditions. A paired sample t-test confirmed there was no difference between breathing rate in both conditions $t(50)=-1.193$, $p=.239$, d = -0.167.

3.3. Results

Descriptive data are reported in Table 7 and correlation matrixes are displayed Tables 8 and 9.

Table 7 Descriptive statistics for study two

	M	SD		
Age	24.96	7.75		
Trait Variables				
DSRS	28.19	9.18		
MSRS	26.35	9.09		
Trait EI – Well-Being	5.53	0.69		
Trait EI – Self-Control	4.45	0.80		
Trait EI – Emotionality	5.05	0.75		
Trait EI – Sociability	4.85	0.64		
Trait EI – Global Score	4.92	0.55		
Performance Variables	*High Pressure*		*Low Pressure*	
	M	SD	M	SD
Remaining Dart Score	1136.39	75.56	1124.33	67.48
Math Errors	4.00	2.32	2.92	2.31
Attention Towards Task	14.23	17.27	13.49	14.01
Attention Towards Self	44.65	33.30	42.98	33.03
Perceived Demands	4.24	1.39	3.61	1.27
Perceived Resources	3.59	1.27	3.76	1.12
Demand/Resource Ratio	-0.80	2.05	-0.11	1.81
Resting CVA	2.41	0.39	2.45	0.43
Task CVA	2.54	0.33	2.56	0.33
Post task CVA	2.52	0.55	2.57	0.46
Reactivity CVA	.123	0.43	-.009	0.38
Recovery CVA	-.013	0.54	.009	0.38
Perceived Stress Post Task	50.92	27.64	42.31	21.59
Perceived Pressure Post Task	5.31	1.50	4.73	1.60
Perceived Relaxation Post Task	2.76	1.74	3.65	1.57
Motivation to Compete	4.16	0.95	4.12	0.79

Note: DSRS = Decision reinvestment total score; MSRS = Movement reinvestment total score; Trait EI = Trait Emotional Intelligence; CVA = Cardiac Vagal Activity

Table 8 Correlation matrix for all variables (Low pressure condition, study two)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	18
1. DSRS	-															
2. MSRS	.77**	-														
3. Trait EI – Well-Being	-.35*	-.29*	-													
4. Trait EI – Self-Control	-.23	-.27	.58**	-												
5. Trait EI – Emotionality	-.29*	-.20	.62**	.53**	-											
6. Trait EI – Sociability	-.17	-.23	.38**	.19	.44**	-										
7. Trait EI – Global Score	-.36**	-.35*	.83**	.76**	.85**	.61**	-									
8. Attention Towards Task	.01	.09	.00	-.17	-.06	-.28*	-.17	-								
9. Attention Towards Self	.11	.17	-.21	-.38**	-.12	-.00	-.26	-.08	-							
10. Demand/Resource Ratio	.24	.05	-.18	-.18	-.07	-.06	-.15	-.05	-.00	-						
11. Resting CVA	-.14	-.04	.14	-.12	.07	.05	.06	.11	.17	-.01	-					
12. Task CVA	.22	.14	-.07	-.21	-.10	.02	-.11	.21	.25	.15	.55**	-				
13. Post task CVA	.01	.07	.05	-.10	.09	-.05	.02	.16	.29*	.15	.69**	.56**	-			
14. Reactivity CVA	.17	.04	-.12	-.05	-.20	.08	.02	-.01	-.12	-.16	-.35*	.17	-.71**	-		
15. Recovery CVA	-.17	-.04	.12	-.05	.20	-.08	-.12	.01	.12	.06	.35*	-.17	.71**	1.00**	-	
16. Math Errors	-.18	-.20	.01	-.02	-.23	-.18	.12	.25	-.00	-.10	-.20	-.16	-.18	.07	-.07	-
17. Dart Score	-.12	-.15	.08	.02	.03	-.07	.03	.26	-.24	-.15	-.17	-.13	-.14	.05	-.05	.64**

*$p < .05$; **$p < .01$

Note: DSRS = Decision reinvestment total score; MSRS = Movement reinvestment total score; Trait EI = Trait Emotional Intelligence; CVA = Cardiac Vagal Activity

Table 9 Correlation matrix for all variables (High pressure condition, study two)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1. DSRS	-															
2. MSRS	.77**	-														
3. Trait EI – Well-Being	-.35*	-.29*	-													
4. Trait EI – Self-Control	-.23	-.27	.58**	-												
5. Trait EI – Emotionality	-.29*	-.20	.62**	.53**	-											
6. Trait EI – Sociability	-.17	-.23	.38**	.19	.44**	-										
7. Trait EI – Global Score	-.36**	-.35*	.83**	.76**	.85**	.61**	-									
8. Attention Towards Task	.31*	.39**	-.17	-.18	-.11	-.09	-.19	-								
9. Attention Towards Self	.03	.05	-.23	-.34*	-.16	-.07	-.27	-.01	-							
10. Demand/Resource Ratio	-.04	-.16	-.21	-.20	-.26	-.15	-.27	-.03	.15	-						
11. Resting CVA	-.05	.01	.06	-.09	.10	.12	.08	.25	.03	-.15	-					
12. Task CVA	-.02	-.059	.01	.06	.09	.11	.11	.01	.01	.09	.28*	-				
13. Post task CVA	.22	.22	-.01	-.09	.03	-.02	-.01	.27*	.23	-.04	.60**	.32*	-			
14. Reactivity CVA	.03	-.05	-.04	.13	-.02	-.02	.01	-.21	-.02	-.21	-.67**	.52**	-.28*	-		
15. Recovery CVA	.23	.26	-.02	-.13	-.02	-.09	-.08	.27	.22	.10	.43**	-.29*	.81**	-.61**	-	
16. Math Errors	.00	.05	-.08	.01	-.20	-.05	-.11	.34*	.13	-.12	-.01	-.01	-.11	.00	-.10	-
17. Dart Score	-.03	-.02	.10	.15	.21	.03	.16	.26	-.03	-.22	-.04	-.07	-.01	-.02	.03	.61**

**p* < .05; ***p* < .01

Note: DSRS = Decision reinvestment total score; MSRS = Movement reinvestment total score; Trait EI = Trait Emotional Intelligence; CVA = Cardiac Vagal Activity

3.3.1. Pressure manipulation checks

The MANOVA showed a significant main effect for condition $F(3, 48) = 5.05$, $p = .004$, $\eta^2 = .14$. Follow up ANOVA's showed a main effect for stress rating after the task with a significant increase in stress following high pressure when compared to low pressure conditions $F(3,48) = 8.68$, $p = .005$, $\eta^2 = .14$, this was also found for pressure ratings $F(3,48) = 4.63$, $p = .036$, $\eta^2 = .08$. A main effect for feelings of relaxation was also found with a significant decrease in relaxation when competing in high pressure when compared to low pressure $F(3,48) = 11.59$, $p < .001$, $\eta^2 = .18$. Results indicate that the pressure manipulations were successful in creating low and high pressure conditions.

3.3.2. Coping-related variables influence on cardiac vagal activity in low pressure

Correlations between all variables are reported in Table 8. As study variables were intercorrelated a series of hierarchical stepwise regressions were performed, the first block was to control for age and gender and the second block was to identify salient predictors (Table 10). Across all step one regressions age and gender had no effect on cardiac vagal activity. Each regression specifies the predictor variables that were entered at each point. For task cardiac vagal activity all trait, state and resting cardiac vagal activity were entered at this stage. The first factor extracted was the level of cardiac vagal activity at rest (adjusted $R^2 = .29$, $p < .001$). The second factor extracted was decision reinvestment (adjusted $R^2 = .08$, $p = .009$). The two factors together predicted 37% of the variance in cardiac vagal activity at task. For post task all trait, state and resting and task cardiac vagal activity variables were entered at this stage. The first factor extracted was cardiac vagal activity at rest (adjusted $R^2 = .46$, $p < .001$). The second factor extracted was the cardiac vagal activity at task (adjusted $R^2 = .04$, $p = .032$). Taken together the two factors combined explained 50% of the total residual variance. For cardiac vagal reactivity trait and state variables and resting cardiac vagal activity were entered at this stage. Task cardiac vagal activity was excluded at this stage as reactivity is derived from the task cardiac vagal activity, the first and only predictor was resting cardiac vagal activity (adjusted R^2 = .10, p = .011). For cardiac vagal recovery trait and state variables and resting cardiac vagal activity were entered at this stage. Task and post task cardiac vagal activity variables were excluded at this stage as reactivity is derived from these tonic cardiac vagal activity variables. The first (and only) predictor extracted was resting cardiac vagal activity (adjusted R^2 = .10, p = .011).

Table 10 Multiple (stepwise) regressions for cardiac vagal activity in low pressure (Study two)

Model	**Unstandardized coefficients**		**Standardized coefficients**	***t***
	B	Std Error	β	
Task CVA				
1 Resting CVA	.42	.09	.55	4.64**
2 Resting CVA	.46	.08	.60	5.29**
DSRS	.01	.00	.30	2.70**
Post task CVA				
1 Resting CVA	.74	.11	.69	6.69**
2 Resting CVA	.59	.12	.54	4.57**
Task CVA	.37	.16	.26	2.20*
Reactivity CVA				
1 Resting CVA	-.32	.12	-.35	-2.66*
Recovery CVA				
1 Resting CVA	.32	.12	.35	2.66*

***p* < .05; ***p* < .01**
Note: CVA = Cardiac Vagal Activity, DSRS = Decision reinvestment score, Trait EI intelligence = Trait Emotional Intelligence
If regressions had no predictors they were excluded from the table.

3.3.3. Coping-related variables influence on cardiac vagal activity in high pressure

Correlations between all variables are reported in Table 9. As study variables were intercorrelated a series of hierarchical stepwise regressions were performed. The first block was to control for age and gender, and the second block was to identify salient predictors (Table 11). Across all regressions age and gender had no covariate effect on cardiac vagal activity. Each regression specifies the predictor variables that were entered at each point. For task cardiac vagal activity all trait, state and resting cardiac vagal activity variables were entered at this stage. The first and only factor extracted was the level of cardiac vagal activity at rest (adjusted R^2 = .06, p = .044). For post task cardiac vagal activity trait, state and resting and task cardiac vagal activity variables were entered. The first factor extracted was resting cardiac vagal activity (adjusted R^2 = .35, p < .001). The second factor extracted was decision reinvestment (adjusted R^2 = .06, p = .018). Taken together the two factors combined explained 41% of the total residual variance in post task cardiac vagal activity. For cardiac vagal reactivity trait, state and resting cardiac vagal activity were entered at this stage. Task cardiac vagal activity was excluded at this stage as reactivity is derived from task cardiac vagal activity. For cardiac vagal reactivity the first (and only) factor extracted was resting cardiac vagal activity (adjusted R^2 = .44, p < .001). For recovery, the first predictor was resting cardiac vagal activity (adjusted R^2 = 17, p = .001). The second was movement reinvestment (R^2 = .06, p = .028), the two factors together predicted 23% of the variance in cardiac vagal recovery.

Table 11 Multiple (stepwise) regressions for cardiac vagal activity in high pressure (Study two)

Model	Unstandardized coefficients		Standardized coefficients	*t*
	B	Std Error	β	
Task CVA				
1 Resting CVA	.24	.11	.28	2.06*
Post task CVA				
1 Resting CVA	.85	.16	.60	5.30**
2 Resting CVA	.88	.15	.62	5.74**
DSRS	.01	.00	.26	2.45*
Reactivity CVA				
1 Resting CVA	-.75	.11	-.67	-6.34**
Recovery CVA				
1 Resting CVA	.61	.18	.43	3.38*
2 Resting CVA	.64	.17	.45	3.66*
MSRS	.01	.00	.28	2.26*
Math error				
1 Attention away from task	.04	.01	.34	2.54*

******p* **< .05; *****p* **< .01**

Note: CVA = Cardiac Vagal Activity, DSRS = Decision reinvestment score, MSRS = Movement reinvestment score

If regressions had no predictors they were excluded from the table.

3.3.4. Dart throwing task performance

For performance, hierarchical stepwise regressions were performed, the first block was to control for resting cardiac vagal activity as when phasic variables were used as a predictor, resting cardiac vagal activity was also controlled for in the first block of the hierarchical regression. The second block was to identify salient predictors of dart throwing task performance. Across all step one regressions resting cardiac vagal activity had no effect on performance in the task. For performance prediction all trait, state and cardiac vagal activity variables were entered at this stage, regressions can be found in tables 10 and 11. For both math error and dart score in the low pressure condition, there were no predictors found. For math error in the high pressure condition the first and only factor extracted was attention to the task (adjusted R^2 = .09, p = .014). The second regression performed for high pressure was for dart score, there were no predictors.

3.4. Discussion

The first aim of this experiment was to assess the predictive role of coping related variables on cardiac vagal activity (derived from heart rate variability). The second aim was to investigate the influence of coping related variables (including cardiac vagal activity) on dart throwing task performance under low and high pressure conditions. Firstly, the predictors of cardiac vagal activity will be discussed and secondly the predictors of dart throwing performance.

3.4.1. Task Cardiac Vagal Activity

Hypothesis one, that emotional intelligence would be positively associated with cardiac vagal activity during the task was not supported. In the high and low pressure conditions resting cardiac vagal activity was the main predictor of levels of cardiac vagal activity during the task. As suggested by the neurovisceral integration model, higher levels of cardiac vagal activity at rest is associated with positive outcomes in relation to emotions, executive functioning and health (Thayer et al. 2009). Cardiac vagal activity reflects effectiveness of self-regulation of the organism (Thayer et al. 2009; Porges 2007) and during stress those with high levels of resting cardiac vagal activity display more effective behavioral responses during a task (Hansen, Johnsen & Thayer, 2003) and display adaptive emotional responding (Ruiz-Padial et al. 2003; Thayer et al. 2009). This suggests that higher levels of cardiac vagal activity at rest led to higher levels of cardiac vagal activity available during the task which can promote the aforementioned benefits for regulation and performance. This is also linked to activation of defensive systems when faced with stress (Porges 1992). A vagal withdrawal serves as a protective function against environmental demand and higher resting levels are seen to be adaptive in this process (Beauchaine et al. 2007; Beauchaine et al. 2001; El-Sheikh et al. 2011).

Conversely, lower resting cardiac vagal activity is linked to a lack of prefrontal control of subcortical activity, this activity is involved in the control of homeostasis, sensory processing and movement (Thayer et al. 2009). Subsequently this can result in poor functioning of self-regulatory systems (Thayer and Lane. 2000; Thayer et al. 2009).

Hypothesis three that decision reinvestment would negatively influence cardiac vagal activity during the task and in recovery was not supported. In the low pressure condition there was a second predictor of decision reinvestment, which suggested that the higher levels of decision reinvestment resulted in higher levels of cardiac vagal activity during the task, therefore hypothesis three is rejected. This opposes findings that suggest higher decision reinvestment leads to reduced cardiac vagal activity during a task under stress (Laborde et al. 2015a), and study one where decision reinvestment reduced effective recovery, which could be linked to the role of decision rumination (Kinrade et al. 2010). However, one has to consider that this finding was only present within the low pressure condition which could be because previous studies have found that the effects of reinvestment are only present within high pressure conditions (Jackson et al. 2006). This finding was also found for task cardiac vagal activity in study one and again was only found in the low pressure condition, this may reflect the interactionist principle of trait activation where individual differences will have a different impact across different pressure situations (Geukes et al. 2013). Therefore it may be that because the low pressure condition was less demanding that the effects of decision reinvestment went against the predictions of previous research (Laborde et al. 2015a: Laborde et al. 2014a). In addition, when comparing the task used in Laborde and colleagues (2015a) research, it was a complex cognitive task which ran continuously and the pace was determine by a computer. Whereas in study two, the task had breaks in between each element for example throwing the dart, followed by the math sum. This could mean that participants had more time to consciously reflect on their own performance in a contemplative and adaptive manner (Watkins 2008), which may then be associated with an increase in cardiac vagal activity.

3.4.2. Post task cardiac vagal activity

Resting cardiac vagal activity predicted for higher levels of cardiac vagal activity during post task in both low and high pressure conditions. In addition to resting cardiac vagal activity, the low pressure condition was also predicted by task cardiac vagal activity. Recovery is a key indicator of the adaptability of the organism as it demonstrates the ability to face a stressful event and then return efficiently to resting level (Stanley et al. 2013). In contrast, lower levels of cardiac vagal activity post task reflects the result of poor self-regulation as the individual is not able to recover from the stressful event (Berna et al. 2014). Furthermore, if individuals experience stressors and poor coping over time, this may eventually facilitate physical wear of the defensive systems impairing recovery (Park et al. 2014). These findings suggest higher levels of cardiac vagal activity at rest fosters more effective recovery due to a greater initial capability to uptake self-regulation resources.

In the high pressure condition the first factor extracted was resting cardiac vagal activity, and this was paired with decision reinvestment as a second predictor. The findings suggested that the higher the levels of decision reinvestment the better the levels of cardiac vagal activity post task. Again like in study one, this finding would go against the hypothesis for the trait itself, particularly that of decision rumination whereby the individual thinks back to decisions they have made (Kinrade et al. 2010). One explanation could be that as the stressor was removed at the point of recovery it prompted relief, those higher in decision reinvestment display a higher cardiac vagal activity post task. Another consideration is the concept that rumination can consist of contemplative and adaptive repetitive thoughts, when the valence associated to those thoughts is positive (Watkins 2008). This can lead to better problem solving, planning and reduces negative moods

(Watkins 2008), which may then be associated with an increase in cardiac vagal activity. Although decision reinvestment has not been assessed with cardiac vagal activity post task before and consequently this speculative interpretation should be investigated further in order to shed light on this finding.

3.4.3. Cardiac vagal reactivity

Hypothesis two, tonic vagal activity would be positively associated with phasic cardiac vagal activity was partially supported. For cardiac vagal reactivity, resting cardiac vagal activity was found as the first predictor in the low and high pressure conditions, with medium to large effect sizes (R^2 = .10 in low and R^2 = .44 in high). It is typical to have large effect sizes for example higher resting cardiac vagal activity was related to higher reactivity levels during a cogntive task f^2 =2.64 (Park et al. 2014). However, in the current study the relationship between reactivity and resting were negatively correlated, meaning that a higher resting level led to a greater drop in cardiac vagal reactivity. One methodological explanation for this difference could be body position as it influences cardiac vagal activity, and Young and Liecht (2010) observed a decrease in cardiac vagal from seated rest to standing rest. Although the baseline was carried out standing, the movement of the arm during the task may have increased metabolic demand and caused a decrease in cardiac vagal activity.

Hypothesis four, that cardiac vagal reactivity would be positively influenced by challenge appraisal, was not supported. Much like the findings of study one, there were no influences of challenge appraisal on cardiac vagal activity. This may be because cardiac vagal activity is not a traditional indicator of challenge and threat cardiovascular indices and along with the shared variance of multiple predictors, the subjective rating did not emerge as a predictor. This is similar to other work exploring subjective and objective challenge and threat measures for example Turner et al. (2012) did not find an association with subjective challenge and threat measures and cardiovascular indices.

3.4.4. Cardiac vagal recovery

The first predictor for cardiac vagal recovery was the same in both low and high pressure conditions, resting cardiac vagal activity, which supports hypothesis two. Much like the findings in the Park et al. (2014) study, resting cardiac vagal activity predicted a positive increase in phasic cardiac vagal activity. Although this relationship has only been found in relation to cardiac vagal reactivity and not recovery. This may suggest that those who have higher resting levels of cardiac vagal activity, are better able to recover from a stressful event as they had higher levels to begin with, suggesting a better ability to self-regulate even after a demand has ceased.

In the high pressure condition a secondary predictor of movement reinvestment was found, a trait that is only supposed to be active with high pressure conditions (Jackson et al. 2006). The higher the levels of trait movement reinvestment, the bigger the increase in cardiac vagal recovery. As movement reinvestment is linked to the conscious processing of skills, it may be that as the task had finished the uptake of coping strategies was no longer needed and thus caused an increase in cardiac vagal activity (Masters 1992). One explanation could be that as the stressor was removed at the point of recovery which prompted a relief, particularly as the movement had finished, it has been suggested that relief is linked to a decrease in sympathetic vascular influences and decreased breathing rates (Kreibig 2010). It is well known that slowing breathing can positively influence cardiac vagal activity levels (Leher et al. 2013) and this breathing pattern is promoted by relief when the threat of danger is removed (Vlemincx et al. 2009). Therefore, it may be worth investigating how trait activation plays a role within recovery, although these were relatively small effects in the current study R^2 = .06.

3.4.5. Dart throwing task performance

Hypothesis five that psychomotor performance would be affected by attention, task cardiac vagal activity and challenge appraisal was partially supported. For the high pressure conditions the first and only predictor extracted for math error was attention away from the task. The more attention that was directed away from the task the more mistakes participants made in the calculations. According to the Attentional Control Theory by Eysenck, Derakshan, Santos and Calvo (2007) anxiety, which often manifests itself within the pressurised environment (Otten 2009), disrupts attention diverting it away from task-relevant stimuli and towards irrelevant stimuli. As this finding was only present in the high pressure condition it may be that attention was disrupted by the additional threatening stimuli such as the second experimenter. Hypothesis five that the task performance would be affected by task cardiac vagal activity and challenge appraisal was not supported. There were no links between psychomotor performance and cardiac vagal activity, this may be linked to previous tasks that solely involve executive functioning having a relationship with cardiac vagal activity (Thayer et al. 2009). The task itself did not test executive function as a separate entity and therefore this could be why the predictions of the previous theory, namely the Neurovisceral integration model, did not apply. A similar study testing visual search performance, which would be loosely connected to selective attention, also found no association with cardiac vagal activity and task performance (Laborde et al. 2015a). Thus suggesting limitations to using cardiac vagal activity as a performance predictor in non- executive tasks.

It was hypothesised (H6), that movement reinvestment would negatively affect dart score, in this case the null hypothesis is accepted. There was no relationship between movement reinvestment and dart score achieved, although this was previously found in other research (Weiss 2011). However methodological differences exist between the Weiss (2011) study and the current study, for example Weiss (2011) promoted participants to non-preferentially focus on external effects of their movements which caused a decrease in dart throwing performance. Whereas in the current study, participants had no interruption in their dart throwing technique, which may be linked to the reason for not replicating results.

3.4.6. Limitations

To fully reflect on the main findings of the study it is important to consider some limitations to the study design. Firstly, sample size may be an issue with the number of variables used within the study. Furthermore, the sample was biased towards athletes from team sports and there has been evidence to suggest that personality-trait-like individual differences can differ across team and individual sports (Laborde et al. 2016). Some methodological limitations exist in that there was no familiarization of both the cognitive and motor aspects of the task and learning effects may have occurred across the two conditions or across the five minute time period. A further limitation of the current study is timing of errors were not taken into account. In future research the timing of errors could be addressed to understand changes in performance across a time period. In addition to this, the task was not specific to the athletes' sport and the findings should be checked with competitive dart players. One consideration regarding the measurement of cardiac vagal activity is that there was a small amount of movement involved when the participants threw the dart which may have had an effect on the accuracy of measurement taken from the cardiac vagal activity reading. The reason for this is that movement can cause more artefacts in the data and produce greater dominance of the sympathetic system, due to metabolic demand, thus influencing cardiac vagal activity (Laborde et al. 2017). It has been stated that in order to gain a valid measure of cardiac vagal activity no movement should take place (Malik 1996). There have been studies that involve movement in the measurement of cardiac vagal activity that link to the current study and have found links to performance (Thomson et al. 2015; Saus et al. 2012). In addition, an effort to control movement was realized through the use of clear instructions to only move the throwing arm and not the whole body (see appendix four) and extra care was taken when scanning for artefacts in the ECG reading.

3.5. Conclusion

To conclude, this study has deepened knowledge of how coping related variables can affect dart throwing task performance and how cardiac vagal activity can be affected throughout a pressurised event. It was demonstrated that resting tonic cardiac vagal activity can predict cardiac vagal activity at both tonic and phasic points throughout an experiment, which strengthens the relationship between cardiac vagal activity levels and self-regulation. It was also showed that the role of attention in psychomotor tasks may only apply in high pressure conditions.. At the theoretical level, it was demonstrated that resting cardiac vagal activity influences other tonic and phasic points (i.e. resting cardiac vagal activity positively influences task cardiac vagal activity in both low and high pressure) and phasic cardiac vagal activity is also influenced by movement reinvestment in high pressure conditions. This further strengthens the need for future research which combines variables in order to get a more holistic view of performance and the use of cardiac vagal activity as an indicator of self-regulatory behaviours pre, during and post task performance.

At the applied level, findings demonstrate the importance of practitioners addressing the role of attention in psychomotor tasks to ensure the attention strategy is beneficial for performance. Consultants may also consider the role of resting cardiac vagal across pressurised tasks given that resting levels predict tonic and phasic states across a dart throwing task. It is recommended that future research addresses the role of cardiac vagal activity and coping related variables under pressure.

Lastly, the same phenomena need to be explored within ecologically valid performance settings to fully understand the effects in sporting competition. Therefore, in order to meet this limitation the final study aimed to address this through assessing the current variables of interest in a simulated sporting competition.

4. THE CONTRIBUTION OF COPING RELATED VARIABLES AND CARDIAC VAGAL ACTIVITY ON PRONE RIFLE SHOOTING PERFORMANCE UNDER PRESSURE

4.1. Introduction

Chapters two and three detailed empirical studies one and two which together showed that resting cardiac vagal activity had a consistent positive influence over both tonic and phasic cardiac vagal activity across a pressurized task. This demonstrates the replicability of findings when utilizing the standardized approach of measuring cardiac vagal activity through the three R's (Laborde et al. 2017), which is a promising discovery for future research recommendations. Furthermore, variables for performance prediction differ across study one and two, as cardiac vagal activity predicted cognitive performance in study one and an element of psychomotor performance was predicted by attention in high pressure only in study two.

Chapter four builds on the previous chapters and presents study three which aimed to bring the research closer to sporting performance by using a sport specific task. As study one and two were conducted within the laboratory these findings are not replicable to specific sporting environments and is far removed real sporting experiences. In a review by Christensen and colleagues (2015) they state that current pressure research that is based within the laboratory is intended to support predictions that would be present in the real world. However, in order to draw conclusive evidence, ecologically valid work needs to be carried out to reduce the dissimilarities in pressure research between the laboratory and the field (Christensen et al 2015). Therefore, the final study increases ecological validity and enables practical recommendations to be drawn within field based settings.

It is well established that an individual's performance during aiming tasks such as dart throwing, golf putting and shooting can suffer from a decrease in performance under pressure (Oudejans et al. 2013; Nibbeling et al. 2013; Schucker et al. 2013; Williams and Cummings 2012). In particular, shooting is of interest as individuals performing the skill have to shoot with speed and accuracy under pressure for example, athletes, police and army samples (Landman et al. 2015; Thompson et al. 2015; Brisinda et al. 2014; Vickers and Lewinski 2012; Vickers and Williams 2012; Causer et al. 2010; Ouedjans 2008; Konttinen et al. 1998). Athletic shooting differs from firearms based shooting regarding the origin of pressure as firearms professionals have to face life threatening scenarios (Vickers and Lewinski 2012) whereas pressure in athletic shooting mainly stems from performance.

Shooting can be described as a "sport of the mind" due to its heavy reliance on mental skills (Coleman 1980). The majority of studies demonstrate that pressure can affect different mechanisms involved in shooting such as gaze (Vickers and Williams 2012; Vickers and Lewinski 2012), cardiac activity (Thompson et al. 2015; Brisinda et al. 2014), psychomotor regulation (Konttinen et al. 1998) and gun motion (Causer et al. 2010); which ultimately may result in altered shooting performance. Furthermore, the individual characteristics of the shooter can affect performance under pressure, for example level of expertise (Landman et al. 2015; Vickers and Lewinski 2012), state anxiety (Causer et al. 2010) and personality traits (Landman et al. 2015). Shooting performance under pressure can also be positively affected by level of experience (Vickers and Lewinski 2012) or previous training under pressure (Nieuwenhuys and Oudejans 2011).

Pressure can have many effects on shooting performance through the shooter as an individual. Recently research has started to examine a range of coping related variables simultaneously in order to further understand performance under pressure (Laborde et al.

2015b). These coping related variables include trait emotional intelligence (Laborde et al. 2011), reinvestment (Laborde et al 2014), challenge and threat appraisal (Laborde et al. 2015b) and cardiac vagal activity (Laborde et al. 2015b; Laborde et al. 2015a). Thus, investigating variables that exist within different scientific domains that directly focus on the personal characteristics of the shooter, may prove a valuable inquest in order to better understand shooting performance under pressure. Subsequently, the purpose of study three was 1) to examine the effects of coping related variables (trait emotional intelligence, reinvestment, appraisals, cardiac vagal activity and attention) on cardiac vagal activity under pressure and 2) to examine the effects of cardiac vagal activity and coping related variables on athletic shooting performance.

4.1.1. Cardiac activity and shooting

Within shooting research heart rate is often a focus due to the stationary and closed nature of the sport, particularly in stationary indoor target shooting. Given there is almost no movement when performing the skill, heart rate is not influenced by movement but mainly psychological processes due to autonomic nervous control (Levenson 2014). It has been shown that higher heart rate and blood pressure may impair shooting performance (Fenici et al. 1999) and slower deceleration of heart rate before shooting was linked to optimal shooting performance (Bertollo et al. 2012). However, studies only assessing heart rate cannot directly inform researchers about psychophysiological reactions to pressure. This is because heart rate alone is influenced by many factors (Levenson 2014) and does not provide information about autonomic flexibility, which can represent higher order controls such as regulated emotional responding (Applehans and Lueken 2006). One measure that enables researchers to understand how an athlete reacts to stress (Laborde et al. 2011), regulates emotion (Thayer et al. 2012) and performance under pressure (Laborde et al. 2015a) is cardiac vagal activity.

Cardiac vagal activity represents the contribution of the parasympathetic nervous system to cardiac function (Laborde et al. 2017) and is a measure derived from heart rate variability (HRV); the change in the time interval between successive heartbeats (Camm et al. 1996; Akselrod et al. 1981). Cardiac vagal activity can index the efficiency of the central-peripheral neural feedback mechanisms, as postulated by the neurovisceral integration model (Thayer et al. 2009). This means that it may serve as a measure of an individual's ability to self regulate through the organisation of physiological resources and response selection when in a changing environment (Thayer and Lane 2000). Higher levels of cardiac vagal activity are suggested to be beneficial as the individual has greater behavioural flexibility and adaptability, whereas lower levels are suggested to be detrimental to adaptation in changing environments (Thayer et al. 2009). Cardiac vagal activity can be measured at different time points, which are called tonic measurements, taken over a period of time to provide an average cardiac vagal activity measurement (Laborde et al. 2017). Laborde and colleagues (2017) suggest that this is taken at three stages: rest, task and post-task which directly reflects the three R's of cardiac vagal activity functioning: resting, reactivity and recovery.

Tonic measures are deemed to be important particularly at rest as it is theorised that higher levels of resting cardiac vagal activity is more beneficial for stress management and emotional regulation (Thayer et al. 2009). In studies one and two resting cardiac vagal activity predicted other tonic states of cardiac vagal activity (task and post task). Therefore, it is predicted that tonic task and post-task cardiac vagal activity variables will be positively related to resting cardiac vagal activity due to its role in effective self-regulation. It is important to consider that to determine the adaptation of the system when demand is placed upon it tonic measurements alone are not sufficient (Thayer et al. 2012). Therefore, the change between tonic measurements provides useful information, which is known as phasic cardiac vagal activity. Phasic cardiac vagal activity can be split into two variables, reactivity and recovery. Cardiac vagal reactivity is the change from the resting state to the onset of a task (Park et al. 2014). Cardiac vagal recovery is from the removal or end of the task to the post-task state (Laborde et al 2017). By assessing phasic cardiac vagal activity, a greater understanding of how the individual is regulating themselves under pressure can be reached. Importantly, tonic and phasic levels may influence each other, as higher levels of tonic cardiac vagal activity at rest have been found to positively influence phasic cardiac vagal reactivity (Park et al 2014). This can be explained because tonic cardiac vagal activity allows for better self-regulation in stressful situations (Thayer et al. 2009).

4.1.2. Cardiac vagal activity and shooting

It is important to consider the role of cardiac vagal activity in differing tasks and situational demands. When tasks involve executive functioning a smaller vagal withdrawal is seen to be effective but if there is increased metabolic demand a larger vagal withdrawal is seen to be effective (Thayer et al. 2009). Cardiac vagal activity has rarely been assessed within shooting performance and it is important to understand the pattern of cardiac vagal activity that is most effective for shooting. Brisinda and colleagues (2015) assessed live cardiac vagal activity reactions of police officers to simulated medium stress and high stress scenarios. They did not find any significant results when assessing cardiac vagal activity (through high frequency (HF) HRV), however they did note an increase in cardiac vagal activity in high stress scenarios when compared with medium stress. This was linked to a potential "shut off" of the sympathetic system and increase in vagal activity when faced with short term life threatening danger (Fenici et al. 2011), which could potentially be linked to effective self-regulation under stress (Thayer et al. 2009). A similar study by Thompson and colleagues (2015) found that participants who had a smaller reduction in cardiac vagal reactivity (from baseline to task) performed better, one element of better performance was taking less time to complete the shooting task. These findings were also mirrored by Saus and colleagues (2006), who found that situational awareness training helped to reduce the decrease in cardiac vagal activity, during a simulated police shooting task. Most recently a study by Gross, Hall, Bringer, Cook, Killduff and Shearer (2017) assessed the use of HRV biofeedback training in an elite shooting athlete. Cardiac vagal activity was manipulated during competition through slow paced breathing and was linked to subjective feelings of optimal performance (Gross et al. 2017). Based on the current theory surrounding self-regulation (Thayer et al. 2009) and previous empirical results (Thompson et al. 2015) it is predicted that a smaller reduction of cardiac vagal activity will be beneficial to shooting performance.

In sum, there have been limited efforts to examine the role cardiac vagal activity plays in shooting performance. There have been some insightful results, although the validity of some of the findings could be questioned due to the measures of HRV used (Thompson et al. 2015). Moreover, the focus seems to be surrounding firearms based shooting, such as police and army samples, while athletic shooting performance has currently received less attention. Study three aimed to address this gap, considering athletic shooting performance in relation to cardiac vagal activity, based on clear psychophysiological theorizing and the neurovisceral integration model (Thayer et al. 2009). In addition to physiological measures such as cardiac vagal activity, it is important to consider the role of other psychological coping related variables that may have an influence on shooting performance, such as personality.

4.1.3. Trait coping related variables and shooting performance

Personality traits are deemed to be stable over time and may directly influence performance under pressure (Mosley and Laborde 2016). Shooting athletes are said to have differing personality traits according to discipline (Coleman 1980) and more recently officers under pressure who were called to more violent situations scored higher in sensitivity to threat (Landman et al. 2015). In the interest of psychophysiology, it is already known that other personality traits can affect cardiac reactions under stress such as reinvestment and trait emotional intelligence (Mosley and Laborde 2015; Laborde et al. 2015b; Laborde et al. 2014a), therefore those traits will be investigated in the current study.

Reinvestment is defined as the “manipulation of conscious, explicit, rule based knowledge, by working memory, to control the mechanics of one’s movements during motor output” (Masters and Maxwell 2004, p. 208). Reinvestment has been shown to influence performance under pressure in both facets of reinvestment, movement (Masters and Maxwell 2008) and decision (Kinrade et al. 2010). Studies have shown that higher levels of movement reinvestment have a negative effect on performance under pressure due to their propensity to consciously control previously learnt skills when placed under pressure (Jackson, Ashford & Norsworthy 2006; Otten 2009). In a similar vein, decision reinvestment is defined as overthinking, through consciously controlling thoughts and/or ruminative thoughts, which is caused by high levels of cognitive effort that negatively affects performance (Kinrade et al. 2010). This has been shown in a decision making task (Laborde et al. 2014a) and a simulated basketball task (Kinrade et al. 2015). Decision reinvestment has also been linked to cardiac vagal activity and those higher in the trait suffer larger declines in cardiac vagal activity when under pressure (Laborde et al. 2014a). However, in both studies one and two decision reinvestment also caused an increase in cardiac vagal activity during the task and caused and a decrease in recovery. Therefore it is predicted that decision reinvestment will have a negative influence on cardiac vagal activity during the recovery and a positive influence during the task.

Another trait associated with performance under pressure is trait emotional intelligence, which represents a constellation of emotional perceptions (Petrides et al. 2007). Trait emotional intelligence has shown its facilitative effects under pressure as it can help to buffer the physiological stress response (Laborde et al. 2011) and facilitate coping (Laborde et al. 2015b). In relation to sports performance trait emotional intelligence has shown links to performance satisfaction through coping (Laborde et al. 2014c), more facilitative appraisals when under pressure (Laborde et al. 2015b), and an increased use of psychological skills to regulate emotion during competition (Lane et al. 2009). In relation to physiology it has been found to predict cortisol secretion within a pressurised tennis serve task (Laborde et al. 2014b), been shown to be a buffer for stress reactions as indexed by HRV (Laborde et al. 2011). Although no relation between trait emotional intelligence and cardiac vagal activity was found in study one or two, both of these studies were laboratory based and did not test actual sporting performance. Therefore it is predicted that higher levels of trait emotional intelligence will positively influence task cardiac vagal activity.

4.1.4. State coping related variables and shooting performance

In addition to trait variables, it is also important to understand the subjective evaluation of psychological components involved with coping related variables. Specifically, the focus here on challenge and threat appraisals, which have been shown to play a role within sporting performance under pressure. Challenge and threat appraisals allow for an understanding of demand and resource evaluations within a pressurised environment (Tomaka et al. 1993). It has been shown that challenge appraisals are associated with successful sporting performance such as before a golf competition (Moore et al. 2013). Elite shooters were more likely to have negative appraisals before or after the shooter missed a target and positive appraisals followed after emotion and problem solving coping (Calmeiro et al. 2014). Although this study did not use the challenge and threat appraisal ratio, it still acknowledges the appraisal process within elite shooters. Therefore it is predicted that challenge appraisal will positively influence shooting performance.

With regard to attention and shooting performance, it has been found that focussing on the target for longer periods of time prior to the shot (quiet eye) was associated to successful rifle shooting performance (Causer et al. 2011). In addition, when under high anxiety conditions police shooters spent more time focussing on threat related cues, however if participants spent long enough focusing on the target, shot performance was not effected by distractions (Nieuwenhuys and Oudejanes 2011). From the findings it is predicted that attention towards the task will positively influence shooting performance.

4.1.5. Study three aims and hypotheses

In summary, current research shows that different coping related variables (cardiac vagal activity, reinvestment, trait emotional intelligence, and challenge and threat appraisals) may influence cardiac vagal activity and shooting performance under pressure. The combination of variables is still relatively under researched with some studies only combining one or two variables to determine performance under pressure (Laborde et al. 2015b). Given no study has investigated all those factors together study three has two aims:

1) To examine the effects of coping related variables (cardiac vagal activity, reinvestment, trait emotional intelligence, appraisals and attention) on cardiac vagal activity under pressure.
2) To examine the effects of cardiac vagal activity and subjective coping related variables on athletic shooting performance.

The hypotheses for the study three are as follows:

- H1) it is predicted that resting cardiac vagal activity will be positively correlated with task and post-task cardiac vagal activity and post-task cardiac vagal activity will be positively correlated with task cardiac vagal activity.
- H2) it is predicted that resting cardiac vagal activity will be positively related to cardiac vagal reactivity and recovery.

- H3) it is predicted that a smaller reduction of cardiac vagal activity from baseline to task will be positively associated to shooting performance.
- H4) it is predicted that decision reinvestment will have a positive correlation with cardiac vagal activity during the task and a negative influence in recovery.
- H5) it is predicted that higher levels of trait emotional intelligence will be positively correlated with task cardiac vagal activity.
- H6) it is predicted that challenge appraisal and attention towards the task will positively influence shooting performance.

4.2. Methods

The same measures were used as study one and two and therefore a brief version is reported here.

4.2.1. Participants

Initially, 45 shooters were recruited for the study however two shooters had heart conditions which would influence HRV readings and five did not complete the personality measures, therefore they were removed from the study. 38 competitive prone rifle shooters were taken forward for the study (30 male and 8 female, M^{age}=55 years old, SD=14.8) and completed the research task at a national competition. Shooting athletes were competing for a mean of 31.1 (SD=20.5) years' and competed at a range of levels (international=11, national=12, regional=2, county=13). A priori sample size estimations were carried out with power leading to an estimate was between 54-79 (all calculations can be seen in appendix five).

4.2.2. Research design

The study used a within subject design which are highly favoured in heart rate variability (Laborde et al. 2017; Quintana and Heathers 2014). Within subject design can foster learning effects of task and habituation of conditions (Laborde et al. 2017), however, this can be reduced through the use of counterbalancing conditions (Laborde et al. 2017). In the current study participants participated in the same task across two different pressure conditions, low and high, which were counterbalanced.

4.2.3. Measures

Personality measures. The Trait Emotional Intelligence Questionnaire (TEIQue) (Petrides and Furnham 2003) measures emotional intelligence as a trait. It was deemed a reliable scale in this study (global score α=.92, wellbeing α=.80, self-control α= 75, emotionality α=.77, sociability α=.83). The Movement-Specific Reinvestment Scale (MSRS) was used (Masters and Maxwell 2008). The MSRS is a nine item scale and was deemed reliable in the current study (α=.87). The Decision-Specific Reinvestment Scale (DSRS) by Kinrade and colleagues (2010) consists of a 13 item measure, which was reliable in the current study (α=.84).

Cardiac vagal activity. HRV was measured using the eMotion Faros 180° (Mega Electronics Ltd, Pioneerinkatu, Finland). Sampling rate was set to 500hz (Laborde et al 2017) and three pre-lubricated disposable electrodes were used (Ambu VLC-00-S/25, Ambu GmbH, Bad Nauheim, Germany).

Perceived stress intensity. A VAS was used to reflect stress intensity (Lesage et al. 2012).

Cognitive appraisal. Two items from the cognitive appraisal ratio were used (Tomaka et al. 1997). Participants were asked “How demanding did you feel the task was?” and “How able were you to cope with the demands of the task?” and were rated on a six point Likert scale rated from 1 (not at all) and 6 (extremely).

Perceived Pressure. The pressure/tension subscales were utilised from the intrinsic motivation inventory (Ryan 1982).

Attention VAS. A VAS was also used to measure the direction of attention during the task. Participants were asked to place a cross on the line to determine where their attention was focused during the task. Two VAS scales were used, the first was anchored by the phrases “towards the task” and “away from the task”, the second was anchored by the phrases “towards self” and “away from self”, which was based on a suggestion from previous research (Laborde et al 2015).

Motivation and effort. Participants completed a single item indicating “How motivated were you to perform to your best in this task?” on a six point Likert scale from 0 (not at all) to 5 (very much so).

Shooting performance. In order to create an appropriate task and pressure manipulations for shooting performance expert opinion was sought on the development of the task. The experts were two athletes competing at international level for 16 years combined and a shooting marshal who previously worked at the Olympic Games. Shooting performance was measured through a simulated competition that consisted of two trials of 10 shots each to be fired in a five minute time frame. A similar study, examining the effects of pressure of gaze in biathletes, used a comparable ten shot procedure (Vickers and Williams 2007). The shooting competition was held at a national shooting centre in England during a national rifle event. The shooting range used electronic targets which automatically calculated the score and therefore shooting score is classed as the total score of the ten shots fired.

4.2.4. Procedures

Pre-testing procedures. Ethical approval was granted from the university ethics board. Participants were recruited at a national meeting through posters and announcements to participate in “heart rate” research that would be a separate competition held at the national meeting. Participants signed up to show their interest to participate at the national centre reception at which there was an information sheet they were prompted to read. The information sheet prompted participants to refrain from heavy exercise 24 hours before attending the testing session and to avoid consuming caffeine and food two hours before the session. This is in order to avoid any confounding effects on HRV measurement during the testing (Laborde et al. 2017).

Participant preparation. Upon arrival to the range all participants provided written informed consent. Participants were told to set up their own shooting area, use their own gun, ammunition and wear their normal shooting attire. Participants then had the three electrodes attached and the Faros 180° device was turned on to begin recording. Once the device was attached the participant was invited to lay on their shooting mat in a comfortable prone position, eyes closed and hands to their sides, to take a resting HRV reading for five minutes. The resting measure was taken in the prone position to ensure the baseline was the same as the position in which the task was carried out (Laborde et al. 2017). After the rest period the first stress VAS was taken.

Performance. Participants were introduced to the competition structure: two trials of five minutes were completed in which individuals had to fire ten shots, with two practice shots before each trial to adjust to conditions, also known as "sighters". Before commencing the trials pressure manipulations were introduced through the competition conditions. Pressure manipulations were created in line with Baumeisters (1984) recommendations and were developed with the international shooters and marshal. To initiate the start, the pressure script was then handed to participants to read and the experimenter checked for understanding of the competitive condition (see appendix one for script). In the low pressure condition participants were told about the competition, monetary rewards for superior performance and interviews for the worst performers. The participants were then instructed to start the task and were not interacted with whilst performing. Once the five minutes had passed participants were instructed to put down their guns and make them safe. They then completed a stress VAS and a five minute HRV measure was taken whilst prone. After this they filled in a battery of subjective questionnaires (stress VAS, perceived pressure, cognitive appraisal, attention direction and motivation).

In the high pressure condition the competitive trial remained the same (five minutes to fire ten shots), however additional conditions were added to increase the pressure to perform well. For example, any shots fired below a seven were scored as zero and the tenth and final shot was worth double points. The adjustments in shot score were not actually taken into account in the final analysis to ensure the task outcome remained the same. In addition to the trial conditions the script included the scores being published on a national shooting website. The performance was also filmed and participants were told the footage would be evaluated by national level coaches. During the task the experimenter aggressively made notes and the participants were told they were looking at facial expressions, body language and reactions to the task. After the second trial the participants were instructed to put down their guns and make them safe, fill in a stress VAS and a five minute HRV post task measure was taken whilst prone. Following this stage the participants filled in the battery of subjective questionnaires again (as in the low pressure condition). Participants were debriefed which included sending the battery of personality questionnaires (TEIQue, MSRS, DSRS) via email to be completed, they were subsequently thanked for their participation.

4.2.5. Data preparation

Firstly, the challenge and threat ratio was determined by dividing demands from resources (Tomaka et al. 1997) and all personality questionnaires were coded and scored accordingly. Secondly, heart rate variability data were processed for artefacts. The artefact correction function of Kubios was used, firstly the very low threshold was applied and data was visually inspected for artefacts that had been corrected, if any. Secondly the low threshold was applied and data was visually inspected again to ensure artefacts were correctly being identified (Laborde et al. 2017). If artefacts were highlighted and confirmed via visual inspection the artefact correction was applied at the low threshold level (1%). Next, indicators of cardiac vagal activity were extracted, in this study high frequency heart rate variability was used, which is between 0.15-0.4 Hz. The variable of absolute power derived from the Fast Fourier Transform was used, which is deemed a reliable measure for cardiac vagal activity (Laborde et al. 2017). Thirdly, data were checked visually for normality via histograms and boxplots. If any outliers existed, they were winsorized (mean + 2x standard deviations). HRV variables were not normally distributed, therefore a log10 transform was applied, in line with procedures used in other research of this nature (Park et al. 2014). After data transformation data were checked again for normality and it was ensured they had a z score of between ±2.58 (Field 2009), all variables were considered to be normally distributed.

4.2.6. Data analysis

To ascertain whether the pressure conditions were successful, a repeated-measures MANOVA was used with condition (low pressure vs. high pressure) set as the within subject factor and the subjective stress variables (Stress VAS after the task, pressure and tension subscales) as dependent variables. A pressure effect would be noted by higher ratings of stress after the task, higher ratings of pressure and lower ratings of relaxation in the high pressure condition when compared to the low pressure condition. To explore the contribution of coping related variables to cardiac vagal activity (resting, task, post task, reactivity and recovery) bivariate correlations were run followed by hierarchical stepwise linear regression analyses. Using a hierarchical regression the following were entered as dependant variables 1) resting, task, post task, reactivity, and recovery cardiac vagal activity, as well as 2) shooting performance under pressure. The first block included age, shooting level and experience, which allowed the researchers to control covariates. The second block was used to explore the contribution of coping related variables (reinvestment, trait emotional intelligence and challenge and threat ratio) to cardiac vagal activity and the contribution of the coping related variables and cardiac vagal activity to shooting performance under pressure. When assessing any phasic variables, or when phasic variables were used as a predictor resting cardiac vagal activity was also controlled for in the first block of the hierarchical regression.

4.2.7. Preliminary checks

In order to ensure all participants were motivated to compete in both conditions, a one item measure asked "How motivated were you to perform to your best in this task?" on a six point Likert scale from 0 (not at all) to 5 (very much so). The participants appeared to be motivated in both the low pressure condition (M=4.15, SD=0.82) and the high pressure condition (M=4.21, SD=0.81). A paired sample t-test confirmed there was no difference between motivation in both conditions $t(37)=.627$, $p=.534$, $d = 0.101$. Breathing rate was also checked across conditions as many shooting athletes control their breathing when they shoot (Gross et al 2017). This was to ensure participants did not change their breathing patterns across conditions which is important for two reasons. Firstly, slow paced breathing can directly affect cardiac vagal activity and secondly, there should be no differences in respiratory frequency between experimental tasks when drawing conclusions from cardiac vagal activity (Laborde et al 2017). To do this the electrocardiogram derived respiration variable was obtained post-hoc from Kubios. This variable estimates respiratory frequency from the R-wave amplitudes which are known to change under chest movements related to respiration (Tarvainen et al. 2014). Therefore, an estimate of average respiratory rate across the task was compared across both low and high pressure conditions. A paired sample t-test confirmed there was no difference between breathing rate in both conditions $t(37)=-1.578$, $p=.123$, $d = -0.255$.

4.3. Results

Firstly, descriptive statistics are reported in table 12 then correlation matrixes of all study variables are presented in tables 13 and 14. Below are the descriptive statistics for the study.

Table 12 Descriptive statistics (Study three)

	M	SD		
Age	55	14.8		
Trait Variables				
DSRS	23.84	9.12		
MSRS	20.63	9.02		
Trait EI – Well-Being	5.28	1.31		
Trait EI – Self-Control	5.42	.88		
Trait EI – Emotionality	2.47	1.03		
Trait EI – Sociability	5.05	.98		
Trait EI – Global Score	4.50	1.65		
Performance Variables	*High Pressure*		*Low Pressure*	
	M	SD	M	SD
Shooting Score	96.26	4.24	97.18	3.36
Attention Towards Task	18.05	22.63	19.00	23.02
Attention Towards Self	45.47	32.51	45.00	32.90
Perceived Demands	3.10	1.35	2.86	1.61
Perceived Resources	4.78	.90	4.57	1.34
Demand/Resource Ratio	.69	.37	.71	.54
Resting CVA	2.53	.61	2.53	.61
Task CVA	2.53	.60	2.51	.62
Post task CVA	2.58	.71	2.42	.68
Reactivity CVA	-.006	.66	-.02	.60
Recovery CVA	.05	.71	-.09	.60
Perceived Stress Post Task	34.15	17.82	31.89	20.77
Perceived Pressure Post Task	3.57	1.82	3.57	1.76
Perceived Anxiousness Post Task	2.81	1.6	3.1	1.59
Motivation to Compete	4.21	.81	4.15	.82

Note: DSRS = Decision reinvestment total score; MSRS = Movement reinvestment total score; Trait EI = Trait Emotional Intelligence; CVA = Cardiac Vagal Activity (High frequency absolute power obtained through the Fast Fourier Transform and Log Transformed).

Table 13 Correlation matrix for low pressure condition (Study three)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1. DSRS	-														
2. MSRS	.23	-													
3. Trait EI – Well-Being	-.27	-.07	-												
4. Trait EI – Self-Control	.08	-.02	.19	-											
5. Trait EI – Emotionality	.09	.02	-.10	-.60**	-										
6. Trait EI – Sociability	-.03	-.13	.15	.59**	-.47**	-									
7. Trait EI – Global Score	.15	.15	-.08	-.22	.23	-.05	-								
8. Attention Towards Task	.28	-.17	.08	.35*	-.22	.36*	.00	-							
9. Attention Towards Self	-.16	-.04	-.18	.28	-.28	.24	-.37*	.33*	-						
10. Demand/Resource Ratio	.07	-.24	-.44**	-.06	.04	.11	-.07	.03	-.00	-					
11. Resting CVA	.16	.05	-.12	.07	-.06	-.15	-.04	-.10	.14	-.10	-				
12. Task CVA	.13	.07	-.04	.46**	-.41**	.27	-.07	.12	-.00	-.11	.50**	-			
13. Post task CVA	.21	.09	.04	.24	-.20	.18	-.11	.09	.14	-.20	.62**	.56**	-		
14. Reactivity CVA	-.02	.02	.07	.39*	-.34*	.42**	-.02	.23	-.14	-.11	-.49**	.50**	-.04	-	
15. Recovery CVA	.10	.03	.09	-.20	.19	-.06	-.05	-.02	.17	-.10	.18	-.38*	.54**	-.56**	-
16. Shooting Score	.02	.15	.16	-.03	-.14	-.13	.06	.22	.16	-.37*	.20	.02	.39*	-.17	.42**

**p* < .05; ***p* < .01

Note: DSRS = Decision reinvestment total score; MSRS = Movement reinvestment total score; Trait EI = Trait Emotional Intelligence; CVA = Cardiac Vagal Activity

Table 14 Correlation matrix for high pressure condition (Study three)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1. DSRS	-														
2. MSRS	.23	-													
3. Trait EI – Well-Being	-.27	-.07	-												
4. Trait EI – Self-Control	.08	-.02	.19	-											
5. Trait EI – Emotionality	.09	.02	-.10	-.60**	-										
6. Trait EI – Sociability	-.03	-.13	.15	.59**	-.47**	-									
7. Trait EI – Global Score	.15	.15	-.08	-.22	.23	-.05	-								
8. Attention Towards Task	.12	-.19	.03	.01	.02	-.06	-.08	-							
9. Attention Towards Self	-.17	-.11	-.26	.22	-.21	.26	-.44**	.34*	-						
10. Demand/Resource Ratio	.13	-.20	-.39*	-.14	.06	-.17	.04	.15	-.03	-					
11. Resting CVA	.16	.05	-.12	.07	-.06	-.15	-.04	.20	.19	-.06	-				
12. Task CVA	-.08	.08	-.05	.45**	-.41**	.31	-.20	.06	.11	-.02	.39*	-			
13. Post task CVA	.25	.24	.06	.21	-.08	.23	.20	-.00	-.14	-.17	.53**	.42**	-		
14. Reactivity CVA	-.22	.03	.06	.34*	-.31	.43**	-.13	-.13	-.07	.04	-.56**	.53**	-.11	-	
15. Recovery CVA	.32*	.16	.10	-.17	.26	-.03	.37*	-.06	-.24	-.16	.20	-.41**	.64**	-.56**	-
16. Shooting Score	.21	.04	.14	.12	-.18	.04	.07	.20	-.02	-.19	.15	-.12	.33*	-.28	.43**

*$p < .05$; **$p < .01$

Note: DSRS = Decision reinvestment total score; MSRS = Movement reinvestment total score; Trait EI = Trait Emotional Intelligence; CVA = Cardiac Vagal Activity (High frequency absolute power)

4.3.1. Pressure manipulation check

The MANOVA showed a significant main effect for condition $F(3, 34) = 3.0001$, p =.032, η^2=.26. However, follow up ANOVA's did not show significant differences in the ratings. This was further investigated in separate paired samples t-test to compare baseline subjective stress levels with task and recovery subjective levels. There was a significant difference between the baseline rating of stress and stress in both low $t(37)$=-6.169, p<.001, d = -1.001 and high pressure conditions $t(37)$=-8.024, p<.001, d = -1.302. In addition, there was a significant difference between baseline stress and recovery in the high pressure condition only $t(37)$=-2.111, p=.042, d = -0.343, suggesting participants found the high pressure condition subjectively harder to recover from.

4.3.2. Coping related variables influence on cardiac vagal activity in low pressure

Correlations between all variables are reported in Table 13. As study variables were intercorrelated a series of hierarchical stepwise regressions were performed, the first block was to control for age and the second block was to identify salient predictors (Table 15). Across all step one regressions age had no effect on cardiac vagal activity. Each regression specifies the predictor variables that were entered at each point. For task cardiac vagal activity all trait, state and resting cardiac vagal activity were entered at step two. The first factor extracted was the level of cardiac vagal activity at rest (adjusted R^2 = .23, p = .001). The second factor extracted was trait emotional intelligence self-control (adjusted R^2 = .17, p < .001). The two factors together predicted 40% of the variance in cardiac vagal activity at task. For post task all trait, state and resting and task cardiac vagal activity variables were entered at step two. The first factor extracted was cardiac vagal activity at rest (adjusted R^2 = .36, p < .001). The second factor extracted was cardiac vagal activity at task (adjusted R^2 = .08, p < .001). Taken together the two factors combined explained 44% of the total residual variance. For cardiac vagal reactivity, trait and state variables and resting cardiac vagal activity were entered at step two. Task cardiac vagal activity was excluded at this stage as reactivity is derived from task cardiac vagal activity. The first predictor extracted was resting cardiac vagal activity (adjusted R^2 = .21, p < .001), the second predictor extracted was trait emotional intelligence self-control (adjusted R^2 = .18, p = .002). Both predictors together accounted for 39% of the variance in cardiac vagal reactivity. For cardiac vagal recovery trait and state variables were entered at step two. Other cardiac vagal activity variables, such as task and post task, were excluded at this stage as recovery is derived from the tonic cardiac vagal activity. There were no predictors for recovery.

Table 15 Multiple (stepwise) regressions for cardiac vagal activity in low pressure (Study three)

Model	**Unstandardized coefficients**		**Standardized coefficients**	***t***
	B	Std Error	β	
Task CVA				
1 Resting CVA	.50	.14	.50	3.47*
2 Resting CVA	.47	.12	.46	3.67*
Trait EI Self-control	.30	.08	.43	3.37*
Post task CVA				
1 Resting CVA	.68	.14	.62	4.73**
2 Resting CVA	.49	.15	.44	3.15*
Task CVA	.37	.15	.34	2.42*
Reactivity CVA				
1 Resting CVA	-.49	.14	-.49	-3.37*
2 Resting CVA	-.52	.12	-.49	-3.37**
Trait EI Self-control	.30	.08	.43	3.36*
Shooting Score				
1 Level of experience	-.94	.42	-.34	-2.23*
2 Level of experience	-.90	.39	-.33	-2.30*
Post Task CVA	1.88	.71	.38	2.63*

***p* < .05; ***p* < .01**

Note: CVA = Cardiac Vagal Activity, Trait EI = Trait Emotional Intelligence
If regressions had no predictors they were excluded from the table.

4.3.3. Coping related variables influence on cardiac vagal activity in high pressure

Correlations between all variables are reported in Table 14. As study variables were intercorrelated a series of hierarchical stepwise regressions were performed; the first block was to control for age and the second block was to identify salient predictors (Table 16). Across all regressions age had no covariate effect on cardiac vagal activity. Each regression specifies the predictor variables that were entered at each point. For task cardiac vagal activity all trait, state and resting cardiac vagal activity variables were entered at this stage. The first factor extracted was trait emotional intelligence self-control (adjusted R^2 = .18, p = .004). The second factor extracted was the level of cardiac vagal activity at rest (adjusted R^2 = .12, p = .001). For post task cardiac vagal activity trait, state and resting and task cardiac vagal activity variables were entered. The first factor extracted was resting cardiac vagal activity (adjusted R^2 = .27, p < .001). The second factor extracted was trait emotional intelligence sociability (adjusted R^2 = .08, p < .001). The third and final factor extracted was attention towards the self (adjusted R^2 = .13, p < .001). Taken together the three factors combined explained 48% of the total residual variance in post task cardiac vagal activity. For cardiac vagal reactivity trait, state variables and resting cardiac vagal activity were entered at this stage. Other cardiac vagal activity variables, such as task and post task, were excluded at this stage, as reactivity is derived from tonic cardiac vagal activity. For cardiac vagal reactivity the first factor extracted was resting cardiac vagal activity (adjusted R^2 = .29, p <.001), the second factor extracted was trait emotional intelligence self-control (adjusted R^2 = .14, p <.001). Taken together these variables accounted for 43% of the variance in cardiac vagal reactivity. For cardiac vagal recovery trait, state variables and resting cardiac vagal activity were entered at this stage, post task and task cardiac vagal activity variables were excluded at this stage, as reactivity is derived from these tonic cardiac vagal activity variables. The first and only factor to be extracted from the model was decision reinvestment (adjusted R^2 = .08, p = .045).

Table 16 Multiple (stepwise) regressions for cardiac vagal activity in high pressure (Study three)

Model	**Unstandardized coefficients**		**Standardized coefficients**	***t***
	B	Std Error	β	
Task CVA				
1 Trait EI Self-control	.31	.10	.45	3.10*
2 Trait EI Self-control	.29	.09	.43	3.13*
Resting CVA	.35	.13	.36	2.63*
Post task CVA				
1 Resting CVA	.62	.16	.53	3.83**
2 Resting CVA	.68	.15	.58	4.41**
Trait EI Sociability	.23	.09	.32	2.41*
3 Resting CVA	.79	.14	.68	5.53**
Trait EI Sociability	.31	.09	.43	3.49*
Attention towards self	-.00	.00	-.39	-3.09*
Reactivity CVA				
1 Resting CVA	-.61	.15	-.56	-4.08**
2 Resting CVA	-.64	.13	-.59	-4.79**
Trait EI Self-control	.29	.09	.38	3.14*
Recovery CVA				
1 DSRS	.16	.07	.32	-2.08*
Shooting Score				
1 Recovery CVA	2.59	.89	.43	2.89*
2 Recovery CVA	3.10	.88	.52	3.50*
Trait EI Emotionality	-1.31	.61	-.32	-2.15*

***p < .05; **p < .01**
Note: CVA = Cardiac Vagal Activity, DSRS = Decision reinvestment score, Trait EI = Trait Emotional Intelligence
If regressions had no predictors they were excluded from the table.

4.3.4. Shooting performance

For performance, hierarchical stepwise regressions were performed, the first block was to control for age, shooting experience and shooting level and the second block was to identify salient predictors of shooting performance. Across all high pressure step one regressions age, experience and shooting level had no effect on shooting performance in the task. In the low pressure condition, level of experience effected performance. For performance prediction all trait, state and cardiac vagal activity variables were entered at this stage, regressions can be found in tables 15 and 16. The first regression performed was for shooting score in the low pressure. The first factor extracted was level of experience (adjusted R^2 = .09, p =.032), the second factor was post task cardiac vagal activity (adjusted R^2 = .13, p = .013). Both predictors together accounted for 22% of the variance in low pressure shooting score. The second regression performed was for shooting score in the high pressure condition. The first factor extracted was cardiac vagal recovery (adjusted R^2 = .16, p = .006), the second factor extracted was trait emotional intelligence emotionality (adjusted R^2 = .08, p = .003). Both together accounted for 24% of the variance in shooting score in the high pressure condition.

4.4. Discussion

The aim of study three was twofold: 1) to examine the effects of coping related variables (cardiac vagal activity, reinvestment, trait emotional intelligence, attention and appraisals) on cardiac vagal activity under pressure and 2) to examine the effects of cardiac vagal activity and subjective coping related variables on athletic shooting performance. Findings will be discussed firstly in line with the predictors of cardiac vagal activity followed by the predictors of shooting performance.

4.4.1. Task cardiac vagal activity

Hypothesis one predicted that resting cardiac activity would positively predict task cardiac vagal activity and hypothesis five predicted higher levels of trait emotional intelligence would predict higher task cardiac vagal activity. Both hypothesis one and five were accepted as in both the low and high pressure conditions trait emotional intelligence self-control and resting cardiac vagal activity predicted task vagal activity. Shooters who had higher resting cardiac vagal activity had higher levels of cardiac vagal activity during the shooting task. High levels of cardiac vagal activity at rest positively influence adaptive emotional responding (Thayer et al. 2009; Ruiz-Padial et al. 2003) and facilitative behavioural responses during tasks (Hansen et al. 2003), which is supported by previous research (Mosley et al. 2017; Park et al. 2014). In addition the effect sizes found for this were large (i.e. rest contributing to post task in low pressure R^2 = .36, and medium for rest contributing to task in high pressure (R^2 = .12) which is similar typical effect sizes for this relationship i.e. higher baseline cardiac vagal activity was related to higher reactivity levels during the task f^2 =2.64 (Park et al. 2014). However, within the Park et al. (2014) study the effect size may have been much larger as there were no other variables entered when exploring this relationship, therefore the smaller effect sizes in the current study may be due to shared variance across multiple predictors. Nonetheless, it could be suggested that individuals with higher resting cardiac vagal activity are better able to meet the demands of the task by successfully regulating themselves in stressful situations. This is directly complemented by the other predictor trait emotional intelligence self-control. Trait emotional intelligence self-control is defined as the ability to regulate emotions, impulses and manage external pressure and stress (Petrides and Furnham 2003). This may suggest those higher in self-control are better able to regulate themselves under stress and subsequently this leads to higher cardiac vagal activity during stressful tasks. In a study comparing task difficulty in self regulation tasks, the higher the perceived difficultly of the task the higher the levels of cardiac vagal activity during that task (η = .25) (Segerstrom and Nes 2007). Much like the findings of this study, those higher in self control had high levels of cardiac vagal activity during the task, which was found to have medium effects in both high pressure R^2 = .18 and low pressure R^2 = .14. This supports theoretical knowledge as it has been shown that higher levels of cardiac vagal activity are linked to better emotional regulation (Park et al 2014) which can be directly linked to the emotion regulation component of self-control (Petrides and Furnham 2003). In addition, this further supports the notion that cardiac vagal activity is an index for self-regulation (Thayer et al. 2012; Park et al. 2014; Porges 2007; Porges

1995). An interesting point to note is the amount of influence in the low and high pressure conditions. In the high pressure condition self-control was the first predictor and in the low pressure condition it was the second. This may suggest that in high pressure conditions the trait of the individual has a stronger influence on task cardiac vagal activity over resting levels of cardiac vagal activity. This could be supported by Landman and colleagues finding (2015) that self-control strength predicted perceived anxiety in the high pressure condition of a police shooting task. Higher anxiety was predicted by lower levels of self-control (Landman et al. 2015), therefore this may be directly associated with poorer self-regulation and reduced levels of cardiac vagal activity (Thayer et al. 2012).

4.4.2. Post task cardiac vagal activity

Hypothesis one predicted that post task cardiac vagal activity would be positively influenced by both resting and task cardiac vagal activity and this was supported. In the low pressure condition post task cardiac vagal activity was predicted by resting and task cardiac vagal activity. An organism's recovery demonstrates the ability to face a stressful event and then return efficiently to resting level (Stanley et al. 2013). These findings suggest higher levels of cardiac vagal activity at baseline fosters more effective recovery due to a greater initial capability to uptake self-regulation resources.

In the high pressure condition resting cardiac vagal activity was the first predictor. Additionally, trait emotional intelligence sociability and attention towards the self came out as predictors for post task cardiac vagal activity. Trait emotional intelligence sociability is defined as the ability to influence other decisions and emotions and also the capability to assert oneself (Petrides and Furnham 2003). It could be suggested that individuals higher in sociability were better able to assert themselves in the high pressure condition where they had negative social influences i.e. the experimenter making notes and element of social evaluation. It has been suggested assertiveness and control over one's environment can be linked to stress resistance (Wallston et al. 1987), however this finding should be explored further. The final predictor was attention towards the self. The more the individual focussed away from themselves, perhaps towards irrelevant cues such as competitors or distractions, the lower the levels of post task cardiac vagal activity. The more attention paid towards the self promoted high levels of post task cardiac vagal activity. It may be that individuals who focussed on themselves made resources available to cognitively reflect on the task rather than sending energy to the body (Segerstrom and Nes 2007), as during this time point the athlete would no longer be exerting physical effort in the task.

4.4.3. Cardiac vagal reactivity and recovery

Hypothesis two was partially supported in that resting cardiac vagal activity predicted reactivity in the low (R^2 = .21) and high (R^2 = .29) pressure condition. However, the relationship between resting and reactivity was negative, in that the higher the resting levels the greater the drop from rest to task. Whereas previous research finds this relationship to be positive and with very large effects, for example the link between resting and reactivity in Park et al. (2014) was positive f^2 = 2.64. Although the resting findings also produced large effects, one important methodological differentiation between these studies is the body position that the experiments were conducted in. It is known that body position effects cardiac vagal activity and specifically the most fluctuations were observed in a supine position (Young and Liecht 2010). This may be a reason for the hypothesis being rejected and the contradiction to most other research, where the baseline and task is usually carried out in a seated position (Park et al. 2012; Park et al. 2014; Laborde et al. 2015b). In addition, it is important to note that the type of task that is being completed does not solely rely on executive function (Thayer et al. 2009) and therefore a withdrawal may be seen as adaptive and that this pattern is seen to be adaptive in prone rifle shooters. Interestingly trait emotional intelligence self-control was seen to enhance cardiac vagal activity under pressure. This could imply that a large vagal withdrawal at the start of a competition allows shooters to meet the demands of the task. Following this those high in self-control are able to enhance cardiac vagal activity after the initial onset of stress – which may subsequently lead to a better recovery. However, this needs further investigation and more detailed methodological considerations to understand this further, perhaps through a detailed breakdown of the stages of competition, or even per shot.

Cardiac vagal recovery in the high pressure condition was predicted by decision reinvestment. The higher the level of reinvestment, the better the recovery from a stressful event. This finding does not support hypothesis four which predicted that decision reinvestment would have a negative influence in recovery . This also contradicts the predictions of the trait, particularly as decision rumination promotes the individual to think back to decisions they have made (Kinrade et al. 2010), which may be a process in recovery from stress. One explanation could be that as the stressor was removed at the point of recovery which prompted a relief, those higher in decision reinvestment display a higher cardiac vagal recovery level. It has been suggested that relief is linked to a decrease in sympathetic vascular influences and decreased breathing rates (Kreibig 2010). It is well known that slowing breathing can positively influence cardiac vagal activity levels (Leher et al. 2013) and this breathing pattern is promoted by relief when the threat of danger is removed (Vlemincx et al. 2009). In addition it is important to consider the nature of the sport that this experiment was conducted in, as shooters consciously control their breathing during shooting, which may also influence cardiac vagal activity levels. Consequently, more research into this finding is needed to shed light on the association of cardiac vagal recovery and decision reinvestment.

4.4.4. Shooting performance

For shooting performance it was predicted that a smaller reduction of cardiac vagal activity during the task will positively influence shooting performance (hypothesis three), which was partially supported. Hypothesis six, that challenge appraisal and attention towards the task will positively influence shooting performance, was not supported. In the low pressure condition firstly level of experience came out as a predictor. This finding suggested that the more experience the shooter has the better their performance will be, which would be supported by previous research (Vickers and Lewinski 2012). The secondary predictor was post task cardiac vagal activity. In that the better the performance the higher the cardiac vagal activity after the task had finished. In the high pressure condition the better the performance, the better the cardiac vagal recovery after the task. Research has supported the link between individual shot performance and heart rate in elite pistol shooters (Bertollo et al. 2012). They found that higher heart rate and slower deceleration occurred before moderate to poor shots and lower heart rate and earlier deceleration occurred before optimal shots (Bertollo et al. 2012). Although this study did not assess cardiac vagal activity or cardiac reactions during recovery, it demonstrates that poor shooting performance is directly linked to higher heart rate and optimal shooting performance is linked to slow and stable heart rate prior to performance (Bertollo et al. 2012). It could be suggested that optimal shooting performance, which prompts slower heart rate and thus increased cardiac vagal activity, subsequently leads to better cardiac vagal recovery. It has also been noted that elevated high heart rates impair shooting performance (Vickers and Williams 2007; Fenichi et al. 1999). This could suggest that during the task if heart rate is higher it may impair shooting performance and if shooting performance was poor this then may lead to a poorer cardiac vagal recovery.

There has been very limited research surrounding cardiac vagal recovery and shooting performance, however recovery seems an important aspect in shooting sports. In shooting competitions athletes fire up to 60 shots which requires mental regulation throughout (Bortoli et al. 2012; Prapavessiss et al.1992). Some of this regulation may come after negative experiences such as missed shots (Gross et al. 2017), which could be considered as part of the recovery process as it is an effort to return to resting level (Stanley et al. 2013). In addition, an observation from the time spent at the shooting range by the primary researcher was that many shooters take rest during competition to break up 60 shot matches. It may be that this time could be used more wisely by shooting athletes, particularly for those who have not performed well. Practitioners working within shooting sports should uncover what athletes do during recovery time between shooting bouts to make it most beneficial to performance. Within this particular piece of research it is hard to ascertain whether poorer cardiac vagal recovery would subsequently lead to a reduction in consequent performance, as this was not explored in the current study. Future researchers should explore multiple shooting rounds and cardiac vagal recovery to understand the accumulative effects of poor/good performance on cardiac vagal recovery and multiple performances.

The secondary predictor of shooting score in the high pressure condition was trait emotional intelligence – emotionality. The findings suggested that those lower in emotionality had a better score in the high pressure condition. Typically it is expected that higher emotionality would promote better performance due to the nature of the trait in recognising ones' emotions (Petrides 2009). However, it may be that in shooters the ability to ignore or be unaware of your emotional state during high pressure competitions may be more beneficial. This may also compare to other findings linked to trait emotional intelligence in this study as self-control played a role at various points. Therefore, it may be that training shooters in self-control is more vital to performance than emotionality, however this would need to be investigated further.

4.4.5. Limitations

There are some limitations that need to be considered in light of the current study. Firstly, the pressure manipulations may have not been fully effective in creating a high and low pressure condition. One reason for this may be that although shooters were aware of the extra pressure (i.e. making notes, being filmed), because of the safety of live firing ranges these had to be performed in the peripheries of the athletes. Some athletes also wear caps to block out external stimuli so this could have stopped them from being exposed to the high pressure manipulations, although they were still psychologically aware of them. This is a limitation of collecting data in ecologically valid settings, however in future other shooting or aiming tasks could be assessed to allow for full pressure manipulation to be carried out (Turner et al. 2013).

Sample size was a limitation within the current study. Given the nature of opportunistic and purposive sampling of the study being held at a national shooting competition, it was difficult to ascertain a large sample. Therefore, we used a posteriori analysis to calculate the minimum effect size that can be reliably detected with the current sample size, which was $f^2 = .47$. A further limitation could be the attrition of sample based on the personality scores being taken afterwards. In future research participants should answer personality questionnaires straight away in order to avoid sample size being affected. In line with sampling, the sample had a range of level of competitors and year's experiences, and it has been shown in other research that experience plays a role in shooting performance under pressure (Vickers and Lewinski 2012). In the current study this was controlled for in the analysis and was not found to affect the results, however future studies may wish to look solely at one shooting level.

Another consideration is that shooting sports naturally lend themselves to controlling breathing whilst performing the skill and controlled breathing is noted to have an influence over heart rate variability measurements (Malik 1996; Berntson et al 1997). In the current study a post-hoc analysis was used to control for breathing influences on heart rate variability measurement during the task and this method has been highlighted to have limitations (Laborde et al. 2017; Quintana and Heathers 2014). The breathing measure was also an average respiratory rate during the task and would not have accounted for the changes in respiratory frequency across the course of the task. Future studies should look to use more advanced methods of assessing breathing during the task, such as using a strain gauge, which measures inhalation and exhalation via thorax dilation (Quintana and Heathers 2014). This would allow respiration patterns of inhalation and exhalation to be identified across the course of competition. Ultimately this would increase reliability of the results and to better understanding the influence of breathing on heart rate variability measurement (Laborde et al. 2017). In addition to breathing, body mass index has been shown to affect heart rate variability measurements (Yi et al. 2012). This variable was not assessed in the current study and should be systematically assessed in future research to avoid confounding effects.

4.5. Conclusion

To conclude, this study has furthered the knowledge surrounding the contribution of coping related variables to cardiac vagal activity across a pressured situation. At the theoretical level, the link between resting cardiac vagal activity and other tonic points (task and post task) has been strengthened throughout stressful tasks. This further affirms the link between resting cardiac vagal activity and self-regulation in situations requiring stress management and emotional regulation (Thayer et al. 2009). In addition, a relationship was noted between trait emotional intelligence self-control and task cardiac vagal activity in both low and high pressure conditions. It may be an interesting avenue to explore training trait emotional intelligence self-control, as it has been shown that trait emotional intelligence can be trained (Campo et al. 2016), to see if this can assist those with poor self-regulation under pressure. It was also showed that shooting performance influenced cardiac vagal activity. Specifically better performance was associated to higher levels of post task and recovery levels. Not only does this strengthen the need to assess the three R's of cardiac vagal activity (Laborde et al. 2017), it shows that successful and unsuccessful performance may influence cardiac vagal activity over and above subjective coping related variables. This indicates the importance of using psychophysiological measures in order to gain a holistic view of performance and should be used in future pressure research.

At the applied level, findings show the importance of understanding what athletes do during recovery periods after both successful and unsuccessful performances in sports that have changes in momentum. Consultants should consider measuring cardiac vagal activity across a competitive event to map changes over the whole 60 shot period. This will enable practitioners to implement suitable interventions for effective recovery periods in shooting competition. This may also be paired with training trait emotional intelligence self-control as it had a beneficial effect on task cardiac vagal activity. The enhancement of both trait emotional intelligence self-control and task cardiac vagal activity may further support an athlete's ability to self regulate under pressure.

5. GENERAL DISCUSSION

Chapter five aims to integrate the collective findings across the thesis in order to draw conclusions in line with previous literature. The section begins with a review of the findings from three studies outlined in chapters two, three and four, which are subsequently addressed through critically answering the aims and objectives of the thesis. Implications for practice are considered with suggestions for practitioners and researchers in the field and limitations are deliberated. Future research directions are highlighted and conclusions of the thesis are drawn with key messages highlighted.

5.1. Review of findings

This thesis was motivated by two main aims:

1) To understand the contribution of coping related variables (cardiac vagal activity, reinvestment, trait emotional intelligence, challenge and threat appraisal and attention) on cardiac vagal activity throughout a pressurised task.
2) To understand the contribution of coping related variables (cardiac vagal activity, reinvestment, trait emotional intelligence, challenge and threat appraisal and attention) on performance under pressure.

These aims were facilitated by the following objectives:

1) To determine the changes in cardiac vagal activity across different points during performance under pressure, specifically resting, task, post-task, reactivity and recovery.
2) To ascertain the role of both trait and state coping related variables on cardiac vagal activity and performance within pressurised environments.
3) To critically understand the predictive ability of the coping related variables on performance in both low and high pressure conditions.

4) To determine the differences in predictive coping related variables across three performance types: cognitive, psychomotor and sport specific.

In order to achieve the aims and objectives three studies were carried out. Study one aimed to address the research gap that few and inconsistent combinations of variables exist across cognitive performance (Laborde et al. 2015a; Laborde et al. 2015b; Laborde et al. 2014a; Park et al. 2013; Park et al. 2012) and test the predictions of the neurovisceral integration model (Thayer et al. 2009). Therefore, study one assessed the contribution of coping related variables and cardiac vagal activity in relation to cognitive performance, specifically working memory. Results showed that cardiac vagal activity was predicted by resting cardiac vagal activity and decision reinvestment. Resting levels were positively associated with other tonic points of cardiac vagal activity and decision reinvestment was shown to influence cardiac vagal activity differently in high and low pressure conditions. With regards to performance cardiac vagal activity during the task predicted working memory performance. This finding was contradictory as it is hypothesised by the neurovisceral integration model that higher levels of cardiac vagal activity will positively influence executive function (Thayer et al. 2009). Within study one findings suggested that lower levels of cardiac vagal activity were found to promote better performance.

Study two built on the findings of study one by moving away from isolated cognitive performance to explore the contribution of coping related variables and cardiac vagal activity on psychomotor performance, specifically a dart throwing task. Results showed that cardiac vagal activity was predicted by resting levels across all tonic states, with the addition of decision reinvestment and movement reinvestment. This demonstrated that task type differences may bring about different coping related variables. Performance was predicted by a attention in the high pressure condition only.

The third and final study extended the findings of study one and two by exploring the same phenomena within an ecological setting and focussed on sport specific performance, prone rifle shooting. Supporting the findings of study one and two, resting cardiac vagal activity predicted other tonic states with the addition of trait emotional intelligence self-control during the task time point and decision reinvestment at the point of recovery in high pressure. The key finding for the sport specific study was that successful and unsuccessful performance directly related to how well the athlete recovered from the pressurised competitive task. For example, in the high pressure condition those who performed poorly subsequently had poor cardiac vagal recovery (from task to post task states). Study three demonstrated that phasic cardiac vagal activity patterns are not only associated with "in task" reactions as shown in study two, but are influenced by performance outcomes.

In order to understand a holistic overview of the PhD findings they have been brought together in a summative table (see table 17). This table displays the findings of studies one, two and three against both low and high pressure conditions and all of the dependent variables of interest. In addition, the table highlights the direction of relationships within the data with green representing a positive correlation and blue representing a negative correlation. This table aims to provide a summary of findings across the study with three key overarching themes emerging within the data:

1. Cardiac vagal activity variables were predicted by a combination of both physiological and psychological factors.
2. Different tasks and pressure conditions promoted different combinations of coping related variables.
3. Performance was predicted by a mix of cardiac vagal activity and coping related variables .

Table 17 Overview of findings across all three empirical studies

Study Number and Pressure Condition	Dependent Variables					
	Resting Cardiac Vagal Activity	Task Cardiac Vagal Activity	Post Task Cardiac Vagal Activity	Cardiac Vagal Reactivity	Cardiac Vagal Recovery	Performance
Study One – Low pressure		Resting CVA (R^2 = .37) DSRS (R^2 = .06)	Resting CVA (R^2 = .29)		DSRS (R^2 = .10)	
Study One – High pressure	X	Resting CVA (R^2 = .34)	Resting CVA (R^2 = .34)		Resting CVA (R^2 = .08)	Task CVA (R^2 = .14)
Study Two – Low pressure	X	Resting CVA (R^2 = .29) DSRS (R^2 = .08)	Resting CVA (R^2 = .46) Task CVA (R^2 = .04)	Resting CVA (R^2 = .10)	Resting CVA (R^2 = .10)	

Study Number and Pressure Condition	Study Two	High pressure		Resting CVA (R^2 = .44)	Resting CVA (R^2 = .35) DSRS (R^2 = .06)	Resting CVA (R^2 = .44)	Resting CVA (R^2 = .17) MSRS (R^2 = .06)	Math error: Attention away from task (R^2 = .14)
	Study Three	Low pressure		Resting CVA (R^2 = .23) Trait emotional intelligence (Self-control) (R^2 = .17)	Resting CVA (R^2 = .36) Task CVA (R^2 = .08)	Resting CVA (R^2 = .21) Trait emotional intelligence (Self-control) (R^2 = .18)		Level of experience (R^2 = .09) Post Task CVA (R^2 = .13)
		High pressure		Trait emotional intelligence (Self-control) (R^2 = .18) Resting CVA (R^2 = .12)	Resting CVA (R^2 = .27) Trait emotional intelligence (Sociability) (R^2 = .08) Attention towards self (R^2 = .13)	Resting CVA (R^2 = .29) Trait emotional intelligence (Self-control) (R^2 = .14)	DSRS (R^2 = .08)	Recovery CVA (R^2 = .16) Trait emotional intelligence (Emotionality) (R^2 = .08)

CVA= Cardiac Vagal Activity, DSRS = Decision Reinvestment score, MSRS = Movement Reinvestment Score, GREEN indicates a positive correlation. BLUE indicates a negative correlation. GREY indicates the effect size associated to the relationship.

As the thesis had two aims the current findings have been split to answer each aim. Firstly, the contributory roles of coping related variables to cardiac vagal activity throughout a pressurised task are addressed followed by contribution of coping related variables and cardiac vagal activity to performance under pressure.

5.2. The contribution of coping related variables on cardiac vagal activity under pressure

Cardiac vagal activity has been shown to provide a useful index for self-regulation under pressure (Smith et al. 2017; Laborde et al. 2015a; Laborde et al. 2015b: Laborde et al. 2014a; Park et al. 2014; Park et al. 2013; Park et al. 2012; Thayer 2009). It has been demonstrated that coping related variables may influence the psychophysiological processes involved in self-regulation, which subsequently effects cardiac vagal activity. Understanding how these coping related variables effect cardiac vagal activity is of great interest and in order to comprehend this contribution the separate coping related variables have been split into contributory themes. These themes are: resting cardiac vagal activity, trait coping related variables and state coping related variables.

5.2.1. The contribution of resting cardiac vagal activity in pressure situations

Resting cardiac vagal activity has proved to be a dominant theoretical and empirical variable within the field of psychophysiology and shown to be an indicator of health, wellbeing and self-regulation (Thayer et al. 2009). It directly reflects self-regulation through the ability to have greater resources for self-regulatory functions such as emotion regulation which is governed by the prefrontal cortex (Thayer et al. 2009), and therefore is directly associated to coping under pressure. It was hypothesised that resting cardiac vagal activity would be predicted by trait emotional intelligence, would positively influence levels of phasic cardiac vagal activity and positively influence cognitive performance. The subsequent findings for resting cardiac vagal activity are now discussed.

Resting cardiac vagal activity was a consistent predictor for one or more of the dependent variables across all three studies. More specifically in all studies resting cardiac vagal activity positively predicted both tonic states (task and post task) across the pressurised task, in low and high pressure. All relationships were found to be statistically significant, positively correlated and had medium (R^2 = .18) to large (R^2 = .46) effects across all studies. It is acknowledged in theory, both by the neurovisceral integration model (Thayer et al. 2009) and the polyvagal theory (Porges 2007), that higher levels of resting cardiac vagal activity has many positive effects when an individual is subjected to a demanding environment such as enhanced stress management, emotional regulation and social functioning (Thayer et al. 2009; Porges 2007). These collective findings show that if an individual has higher levels of cardiac vagal activity at rest, then it is more likely that they will remain high across a stressful task. Therefore, the consistency of resting cardiac vagal activity as a predictor for self-regulation mechanisms across pressurised performance is supported by the current findings and confirms previous theory (Thayer et al. 2009). These predictions were expected and supported the hypothesis that resting cardiac vagal activity would predict other tonic states, however, the findings for phasic cardiac vagal activity were not as consistent.

The prediction of phasic patterns was less consistent across all studies as resting cardiac vagal activity did not always predict the reactivity or recovery phases. It was hypothesised that resting cardiac vagal activity would predict phasic phases, specifically reactivity. Previous research examining if resting cardiac vagal activity could predict reactivity found that those higher in resting levels had cardiac vagal enhancement when faced with a task and those who had lower levels suffered a greater withdrawal, which as found with very large effect f^2 = 2.64 (Park et al. 2014). This positive relationship between resting cardiac vagal activity and reactivity was not found in any of the three studies. On the contrary, in studies two and three resting levels negatively influenced cardiac vagal reactivity, which would not support previous work (Park et al. 2014). The explanation used for this is that tasks not solely involving executive function may require the opposite pattern for example, a decrease in order to meet the demands of the environment. The nature of the task in both study one and the Park et al. (2014) study was based on computer generated tasks which may be considered to be far removed from the sporting environment. In addition, both study two and three had different body positions that the task was carried out in (standing and prone), which may have also influenced findings (Young and Leicht 2011), and the demands on the autonomic systems (Porges 1992).

There is limited research regarding how resting cardiac vagal activity would influence cardiac vagal recovery, with few studies examining this relationship (i.e. Stanley et al. 2013). Although predictions were also made from findings that suggested higher resting cardiac vagal activity would increase reactivity (Park et al. 2014). This was supported in study one (high pressure R^2 = .08) and study two in both low (R^2 = .10) and high pressure (R^2 = .17), which were all positive relationships between resting and recovery cardiac vagal activity levels. This may suggest that those who have higher resting levels of cardiac vagal activity, are better able to recover from a stressful event as they had higher levels to begin with, suggesting a better ability to self-regulate even after a demand has ceased. Although this finding was not consistent as this did not emerge in study three, suggesting that further research is needed to understand the relationship between resting and recovery vagal activity in different contexts.

Therefore, from the current findings it can be suggested that the relationship between tonic and phasic cardiac vagal activity is not yet clearly defined. There have been limited endeavours to investigate the role of these different tonic and phasic points across different environmental and task demands, and given it can indicate adaptability and self-regulation (Thayer et al. 2009), these findings are of interest. This supports the need to investigate the role of resting cardiac vagal activity on phasic elements to further understand their relationship. Furthermore, tonic and phasic cardiac vagal activity should be researched in ecological settings to further understand potential facilitative patterns in sport.

5.2.2. The contribution of traits on cardiac vagal activity

Traits related to the coping process have been shown to have positive and negative influences on patterns of cardiac vagal activity, for example debilitating cardiac vagal activity through reinvestment (Laborde et al. 2015a; Laborde et al. 2014a) and facilitating cardiac vagal activity through trait emotional intelligence (Laborde et al. 2015b). Coping related traits contributed to cardiac vagal activity patterns in all studies. These contributions were different across studies one, two and three however there were two main traits that were more consistent predictors across all three contexts. These were decision reinvestment and trait emotional intelligence and will now be discussed in turn.

5.2.2.1. The role of decision reinvestment

It was hypothesised that decision reinvestment would negatively affect task cardiac vagal activity based on previous findings (Laborde et al. 2015a; Laborde et al. 2014a). Across all three studies, decision reinvestment was a predictor of task, post task and recovery cardiac vagal activity, although the effects of the trait were mixed and unexpected across the three studies. The first unexpected result was the discovery that decision reinvestment caused an increase in task cardiac vagal activity in study one, task and recovery in study two, and recovery in study three. Study one and two found that decision reinvestment predicted a greater increase in task cardiac vagal in a cognitive task within the low pressure conditions only. This finding was only present within the low pressure condition in the present study and the effects of reinvestment are usually only present within high pressure conditions (Jackson et al. 2006). This could be linked to the principle of trait activation, where individual differences in personality will have a differing impact across different pressure situations (Geukes et al. 2013). For example, it may be that decision reinvestment may have reverse effects in low pressure conditions, although this was not this case in the high pressure condition in study two – where it was found to increase post task cardiac vagal activity. Another possible explanation could be that rumination can consist of contemplative and adaptive repetitive thoughts, when the valence associated to those thoughts is positive (Watkins 2008). This can lead to better problem solving, planning and reduces negative moods (Watkins 2008), which may then be associated with an increase in cardiac vagal activity. Although all of these findings were associated with small effects R^2 = .06-.08, meaning that the contribution to the variance was small.

The final finding that was also new and unexpected was the relationship between decision reinvestment and cardiac vagal recovery. In study one in the low pressure condition recovery was impaired by higher levels of decision reinvestment. This is partially supported with previous research as higher levels of decision reinvestment caused a larger decrease in cardiac vagal activity during a task (Laborde et al., 2014a) with medium effect (partial η^2 = .19) and the current study also found a medium effect (R^2 = .10). Although different cardiac vagal activity variables were predicted, and the Laborde et al. (2014a) study did not measure recovery, the similarities between the two studies however is that the task was solely cognitive and involved executive functions. In study three decision reinvestment was found to have the reverse effects on cardiac vagal recovery (also with medium effect R^2 = .16), as those higher in the trait had an increase during recovery. A reason for this could be that, when the task was not directly associated to executive function, the point at which the stressor was removed prompted relief. The emotion of relief has previously been linked to a decrease in sympathetic vascular influences and decreased breathing rates (Kreibig 2010). It is well known that slowing breathing can positively influence cardiac vagal activity levels (Leher et al. 2013) and this breathing pattern, commonly known as sighing, is promoted by relief when the threat of danger is removed (Vlemincx et al. 2013; Vlemincx et al. 2009). Sighing is partly controlled by vagal influences (Harver and Loig 2000) and it has also been shown in multiple studies that relief is associated with "reset" of cardiac vagal activity which is said to be related to a relaxation response (Peng et al. 2009; Mishima et al. 1999; Sakakibara et al. 1994). As decision reinvestment had yet to be examined with cardiac vagal reactions after a stressful task these findings are a new contribution to knowledge. It is important to consider what psychophysiological processes occur after a stressful event as athletes rarely face a single stressor in a sporting competition. The nature of multiple stressors and momentum in sport naturally leads to periods of mental recovery, such as a break in tennis or waiting for a rugby kick to be taken. Consequently, more research into this finding is needed to further examine the association of cardiac vagal recovery and decision reinvestment.

Movement reinvestment was only a predictor for recovery in study two. It could be suggested that as this study required the most movement, in terms of actual gross movement to performance the skill, then perhaps this is why it only came out as a predictor in this context. By definition, movement reinvestment is the conscious control of movement (Masters 1993) and it may be more pronounced in gross skills. In similar research, movement reinvestment was not found to effect cardiac vagal activity (Laborde et al. 2015a), but this was limited to a cognitive task therefore this would need further investigation in more motor based tasks. Another consideration may be that the participants had very little dart throwing experience and therefore conscious control of movement may not have been present as motor programs were not unconscious.

5.2.2.1. The role of trait emotional intelligence

It was hypothesised that trait emotional intelligence would positively influence cardiac vagal activity at both the resting and task levels of cardiac vagal activity based on previous findings (Laborde et al. 2015b; Laborde et al. 2011). There were no consistent patterns across trait emotional intelligence over the three studies and it only emerged as a predictor in study three. Within study three, the factor of self-control was directly related to enhancing cardiac vagal activity at task and reactivity in both low and high pressure, with medium effects i.e. $R^2 = .17$. This is similar to the findings in Laborde et al. (2015a) who found that those higher in emotionality had higher task cardiac vagal activity, although this was only found with small effects $R^2 = .05$. A possible explanation for larger effects in the current study is the theoretical similarities between self control and self regulation. Trait emotional intelligence self-control is defined as the ability to regulate emotions, impulses and manage external pressure and stress (Petrides and Furnham 2003). This may suggest those higher in trait emotional intelligence self-control are better able to regulate themselves under stress and subsequently this leads to higher cardiac vagal activity during stressful tasks. It has been shown that higher levels of cardiac vagal activity are linked to better emotional regulation (Park et al. 2014) which can be directly linked to the emotion regulation component of self-control (Petrides and Furnham 2003). The findings from study three further supports the notion that cardiac vagal activity is an index for self-regulation (Thayer et al. 2012; Park et al. 2014; Porges 2007; Porges 1995). Prior to this research there was little empirical evidence to suggest trait emotional intelligence self-control could enhance cardiac vagal activity, therefore this finding contributes to new knowledge in the field.

Self-control is considered to be one of the most beneficial traits as it has many positive influences on an individuals' behaviour and outcomes (de Ridder et al. 2012), however there are many ways to measure it. The self-control factor of trait emotional intelligence may be conceptualized differently to other self-control measures. For example, the self-control scale assesses the individual's ability to override or change inner responses and to interrupt unwanted behaviours and refrain from acting on impulses (Tangney et al. 2004). Therefore, in future research it is important to consider more than one measure of self-control in order to fully understand the role of self-control and cardiac vagal activity, rather than just one conceptualization. This is crucial to standardize findings across different theory and conceptualisations of self-control to ensure the findings can be replicated across samples and performance domains.

5.2.3. The contribution of state variables on cardiac vagal activity

State coping related variables were of interest in the thesis as combining both trait and state coping related variables provides a more holistic approach to the prediction of performance under pressure. In particular, the subjective appraisal of the environment has been shown to directly affect levels of cardiac vagal activity (Laborde et al. 2015b) and attentional processes under pressure have been shown to be facilitated by higher levels of cardiac vagal activity (Park et al. 2013; Park et al. 2013). With regard to appraisal, it was hypothesized that threat appraisal would cause a greater cardiac vagal withdrawal at the onset of the task and be associated with lower levels of cardiac vagal activity during the task (Laborde et al. 2015b). In the thesis, the challenge and threat appraisal did not come out as a predictor of cardiac vagal activity or performance at any point across all three studies. Challenge and threat appraisals have been found previously to help predict performance when athletes are more challenged (Moore et al. 2013; Turner et al. 2013) and these appraisals have a reducing effect on cardiac vagal reactivity when athletes are threatened (Laborde et al 2015b). It may be because of the shared variance of the multiple variables that the appraisal process did not have enough influence over and above the other variables. When it has been previously explored in similar research, threat appraisal was found to reduce task cardiac vagal activity, however the effect size was small R^2 =

.03 (Laborde et al. 2015b). Cardiac vagal activity does not belong to the traditional cardiac indicators of challenge and threat (Blascovich and Mendes 2000) and therefore may not be a consistent predictor of subjective challenge and threat states. When comparing this to the findings of the trait coping related variables, which provided consistent influences over cardiac vagal activity, it may be that the trait influence is more stable across pressure situations (Pervin 1996). Traits are considered consistent predictors of behaviour across time and a range of situations (Pervin 1996) and therefore may be more salient predictors when examining the reactions of cardiac vagal activity under pressure. This may help to guide future researchers in their decisions of choosing variables that may directly influence cardiac vagal activity under pressure, given the relationships found within the current thesis.

The other state variable of interest in this thesis was attention. It is well known that attention will narrow in pressure situations and when an individual is experiencing anxiety (Eysenck et al. 2007). Attention is also directly linked to the neurovisceral integration model as attentional processes, such as selective attention and sustained attention, are linked to executive functions such as working memory and therefore would be positively associated with cardiac vagal activity (Thayer et al. 2009). It was predicted that attention would be facilitated by higher levels of resting cardiac vagal activity, given higher resting levels were associated to better attentional strategy under load (η^2 = .10) (Park et al. 2013). Attention was only a predictor in studies two and three and it did not play a role when based on a computer generated task. It could be suggested that the aiming nature of the tasks in studies two and three promoted attention to play more of a role within pressure situations. However, only study three found a relationship between cardiac vagal activity and attention, in the high pressure condition attention towards the self promoted an increase in cardiac vagal activity. It could be suggested that when an individual focusses on themselves in the high pressure condition it allows for the uptake of resources to help the individual recover after stress. It has been shown that higher levels of cardiac vagal activity are beneficial to attention related performance when under high load (Park et al. 2013: Park et al. 2012) and therefore this may carry through to recovery. In addition, both Park et al. (2013) (η^2 = .10) and the current study (R^2 = .13) found medium effect sizes in relation to attention and cardiac vagal activity. Although there were only limited findings regarding attention and cardiac vagal activity it reinforces the link between attentional capacity and cardiac vagal activity (Park et al. 2013; Park et al. 2012; Thayer et al. 2009). Moreover, this finding goes above and beyond previous research where attentional capacity has only been measured at the performance level and not at the subjective level (Park et al. 2013; Park et al. 2012). This demonstrates the importance of understanding the subjective processes involved in attention that may directly influence psychophysiological reactions under pressure.

5.3. The contribution of coping related variables and cardiac vagal activity on performance under pressure

The previous knowledge surrounding the contribution of coping related variables and cardiac vagal activity performance was narrow and has only been explored in a small amount of studies (Laborde et al. 2015a; Laborde et al. 2015b; Laborde et al. 2014a; Park et al. 2013; Park et al. 2012). Combinations of variables remained limited for performance predictions for example, decision reinvestment and cardiac vagal activity (Laborde et al. 2014a) and appraisal and attention (Laborde et al. 2015b). In the current thesis, one overarching finding in terms of performance was that cardiac vagal activity came out as a predictor for performance two of the three studies, thus supporting the work of other researchers (Laborde et al. 2015a; Laborde et al. 2014a; Park et al. 2013; Park et al. 2012). Collectively these findings demonstrate the importance of using physiological variables when trying to predict performance under pressure. Interestingly, cardiac vagal activity did not always predict performance dependant on pressure condition. For example it was only a predictor for cognitive performance in high pressure in study one. This has also been reflected in previous findings (Laborde et al. 2015a), which may suggest that the influence of cardiac vagal activity is greater in high pressure conditions and when the task is solely executive. A potential explanation for this is that in high pressure conditions individuals have to use far more self-regulatory processes, for example emotion regulation, in order to perform more effectively and these processes have been linked to cardiac vagal activity (Thayer et al. 2009). However, the differences in cardiac vagal activity patterns need to be further explored to understand this relationship in more detail.

In relation to the type of cardiac vagal activity variables that predicted performance, there was a mix of both tonic and phasic variables. In study one there was a negative relationship between working memory performance and levels of task cardiac vagal activity, which is a tonic variable. Tonic variables have been found to have medium effects on working memory performance as supported by Laborde et al. (2015a) who found that resting cardiac vagal activity predicted performance ($R^2 = .13$) and the current study task cardiac vagal activity was extracted as the predictor ($R^2 = .14$). Although the current study findings were not theoretically supported by the neurovisceral integration model as higher executive functioning performance is associated to high levels of cardiac vagal activity (Thayer and Lane 2000). It may suggest that tonic cardiac vagal activity variables are considered a predictor for cognitive based performance. This needs to be further explored with other cognitive tests and tonic cardiac vagal activity measurement to further understand the role of cardiac vagal activity and executive performance.

In study three phasic variables contributed to performance prediction. Phasic variables are yet to receive a large amount of empirical support to understand how changes in cardiac vagal activity directly influence reactions to performance. In study three, cardiac vagal recovery was directly related to shooting performance. It was shown that performance outcome (successful or unsuccessful) influenced recovery levels, something which needs to be investigated further in future research. Those having better situational awareness have been shown to have better recovery (Saus et al. 2012), however this wasn’t directly associated with performance in the task. The final study creates new knowledge surrounding performance outcome and cardiac vagal recovery in athletes. This was potentially only found in study three and not one and two because they were not domain specific and therefore performance was unrelated to the sports they participated in. Again, this suggests phasic patterns of cardiac vagal activity need to not only be investigated in differing pressure conditions, but differing tasks and ecological settings. Within the current body of knowledge, there are few findings demonstrate the link between cardiac vagal reactivity, differing situational demands (types of pressure conditions) and task type (cognitive vs psychomotor). This further shows the importance of considering cardiac vagal activity as an indicator for self-regulation on a case-by-case and situational basis. In addition, this highlights the need to understand the nature of cardiac vagal reactivity and recovery when predicting different tasks that do not directly involve executive function, which was the basis for previous theory (Thayer et al. 2009). This context-specific approach was also highlighted as a new development for the neurovisceral integration model in recent research (Smith et al. 2017). Therefore, this adds knowledge at the theoretical level as phasic variables have not been systematically used in performance prediction outside of executive tasks.

Cardiac vagal activity was not the sole predictor of performance in study three trait emotional intelligence and attention also played a role in performance, emotionality was associated with a poorer shooting score. Again it may be that traits also need to be considered on a case-by-case and situational basis in order to understand their contribution to performance prediction. This would be in line with personality based research which examined trait activation, as the influence of some traits may only be present in specific situations (Geukes et al. 2013; Tett and Guterman 2000).

Attention was the only predictor of performance in the dart throwing task (math error, high pressure) and this could suggest that this task demanded the most attention from participants as it had both cognitive and motor aspects. The need to use selective attention has been shown to improve attention related performance (Park et al. 2013; Park et al. 2012) and therefore this may be a reason why the ability to focus on the task and to ignore distractions was a predictor along with cardiac vagal reactivity. In addition, this finding is in line with previous combination research as attention was a predictor of visual search performance (Laborde et al. 2015b).

From the collective findings of the thesis, it is clear that different cardiac vagal activity variables and subjective coping related variables play differing roles depending upon the task. This echoes the findings from multiple studies such as Laborde et al. (2015b) who found a mix of threat appraisal (R^2 = .09) and attention (R^2 = .04) promoted a 13% variance in performance. A direct comparative example from the thesis is linked to study three as cardiac vagal recovery (R^2 = .16) and emotionality (R^2 = .08) promoted a 23% prediction of the variance in performance. Although the predictors were not consistent across the studies, suggesting that there is not one fixed combination of coping related variables are needed for successful performance and therefore it may be that using this approach is useful to understand different task demands. The most consistent predictor of performance across studies one and three was cardiac vagal activity. Specifically, the finding related to phasic patterns post performance in study three is a novel contribution to the field as it has yet to be suggested how phasic patterns may influence reactions to performance outcomes. This notion adds a new layer of knowledge to current theory, particularly the predictions of the neurovisceral integration model on which this thesis is based. Given the novel contribution to the area from the collective findings of the PhD, the theoretical implications regarding the extension to the neurovisceral integration will now be discussed.

5.4. Theoretical implications: Extensions of the neurovisceral integration model

This thesis was based on the prediction of the neurovisceral integration model and in order to further understand the contribution to theory, the current findings will be compared to the original model. The neurovisceral integration model provides a sound theoretical base for the use of cardiac vagal activity as an indicator of self-regulation under pressure (Thayer et al 2009). However, the predictions of the model are mainly focussed on resting levels of cardiac vagal activity being beneficial for self-regulation under pressure (Thayer et al 2009). The neurovisceral integration model suggests that higher levels of cardiac vagal activity at rest is associated with positive outcomes at the level of emotion, executive functioning, and health (Thayer et al. 2009b). The thesis has shown that resting levels help to predict other tonic states of cardiac vagal activity across all three studies; which supports the model. However, resting cardiac vagal activity did not predict successful performance under pressure through effective self-regulation. It was apparent from studies one and three that task and recovery vagal activity was important in order to facilitate performance or understand the influence of performance outcome on subsequent recovery. Therefore, the present research extends knowledge from the current theory where resting cardiac vagal activity has previously had a considerable influence (Thayer et al. 2009) and highlights the need to explore phasic cardiac vagal activity variables.

Limited attention has been paid to the phasic patterns that may exist to facilitate superior performance in the neurovisceral integration model. The model only offers predictions of cardiac vagal reactivity patterns for executive performance and emotion regulation (Thayer et al. 2012; Thayer et al. 2009). More specifically, a smaller vagal withdrawal is better for executive performance (Thayer et al. 2012). However, it does not provide insight into performance that may not solely rely on executive functioning, like the demands of the sporting environment within study three. In this study levels of recovery were linked to the performance outcome which was a novel finding. The neurovisceral integration model does not offer any clear predictions for cardiac vagal recovery (Thayer et al. 2012; Thayer et al. 2009). This highlights the importance of collecting cardiac vagal activity measurements across the duration of a stressful task in order to understand the adaptations that happen throughout (Stanley et al. 2013). This new knowledge provides an extension to the current neurovisceral integration model, where cardiac vagal recovery had not previously been considered.

In order to fully understand complexity of behaviour under pressure the systematic consideration of the three R's (resting, reactivity and recovery) is crucial (Laborde et al. 2017). It has been shown in the current research that taking multiple measurements of cardiac vagal activity throughout a pressurised task allows for better understanding of the psychophysiological processes involved. Therefore, the neurovisceral integration model should be adapted to consider the role of the three R's and include predictions of facilitative and debilitative patterns for health, wellbeing and performance. In addition, although the model is based within psychophysiology it does not take into account the other variables that may be important for performance under pressure such as trait emotional intelligence. It was shown in the current research that a combination of subjective and physiological variables helps in the prediction of performance and therefore such psychophysiological models should include both psychological and physiological variables.

5.5. Implications for applied practice

The current findings not only help to extend knowledge and theory they also provide some useful insights for practitioners working within the applied field. It was demonstrated across all three studies thus supporting existing theory, that resting levels were beneficial to levels of cardiac vagal activity throughout a pressurised task (Thayer et al. 2009). Practitioners may want to consider how to increase an athletes' resting cardiac vagal activity in order to increase the athletes' ability to uptake self-regulation resources. One practical and mechanical technique that can be used to increase cardiac vagal activity is slow paced breathing (Gross et al. 2017; Lehrer et al. 2013; Paul and Garg 2009). This skill is simple to administer for practitioners and can be used anywhere by athletes (Gross et al. 2017; Lehrer et al. 2013). By implementing a technique, such as slow paced breathing, practitioners can give athletes an effective skill to help to boost their cardiac vagal activity before times of stress such as pre-race. However, it is not only a technique to improve resting levels and practitioners should consider the nature and demands of the sport they are working in. Based on the findings from the shooting research (study three, chapter four) it could be that interventions can be implemented to help to improve cardiac vagal recovery after a negative performance experience. Biofeedback has already been explored within elite shooting and was shown to improve subjective feelings of performance management (Gross et al. 2017). A recent systematic review of the use of heart rate variability biofeedback in sport suggested that it is a safe, effective and easy to learn method to improve sports performance (Jimènez-Morgan and Mora 2017). Practitioners should be made aware of the impact of cardiac vagal activity on performance and the fact that it can easily be manipulated by effectively controlling breathing (Lehrer et al. 2013).

Practitioners may also want to investigate the personality and individual differences of the athletes they are working with as these were directly associated with levels of cardiac vagal activity in all three studies. It has already been shown that trait emotional intelligence can be improved through training (Campo et al. 2016) which provides another avenue for the practitioner to help athletes increase their cardiac vagal activity in pressurised situations. As shown consistently in study three, trait emotional intelligence self-control was found to increase cardiac vagal activity during the task and during reactivity which could be beneficial to performance. In addition to this, training stable traits may be beneficial to improve performance and to enhance physiological reactions over a longer period of time, rather than just at a specific time point. For example, practitioners may want to use a similar approach to Campo and colleagues and apply an educational training programme to enhance awareness of traits (Camp et al. 2016).

Overall, the main implication for practical application of these results would be to encourage practitioners to use both psychological and physiological measures in their practice. Assessing one area of the athlete is not sufficient to help improve or predict performance and practitioners should adopt a more holistic approach to performance enhancement under pressure. These approaches may be task specific and include different focus combinations such as trait and cardiac vagal activity (study three) or decision reinvestment and cardiac vagal activity (study one and two). In addition, there may be multiple ways to help increase an athletes' cardiac vagal activity both mechanically (Lehrer et al. 2013) but also through education based training in traits (Campo et al. 2016), particularly those that have been related to cardiac vagal activity, such as trait emotional intelligence (Laborde et al. 2015a; Laborde et al. 2011) and reinvestment (Laborde et al. 2014).

5.6. Limitations of the research process

The limitations highlighted in the studies of this thesis offer potential areas for future theoretical and research developments. One limitation of the thesis could be the within subject design adopted across all studies through the overarching methodological design. Within subject design can promote learning effects of a task and habituation of conditions may occur (Laborde et al. 2017). Particularly in this thesis participants competed in the same task twice and with pressure conditions that were delivered in a similar manner. It is important to consider these points in the research process as future research may want to examine this approach using a different study design such as single case approaches.

However, these confounding effects were reduced by implementing counterbalanced conditions across all studies. Moreover, within subject designs are recommended in heart rate variability research as it allows for optimal experimental control, reduces individual differences in respiratory rate and reduces the impact of external variables such as amount of sleep (Laborde et al. 2017; Quintana et al. 2014).

Another consistent limitation with the current thesis is sample size. The nature of this very project would always call for a large number of variables to be brought together in order to understand their combined effects, which in turn requires large samples. The time intensive nature of experimental research also affected the amount of data collected. It is acknowledged within this thesis that statistical power may be lacking and the current findings may be influenced by this. However, some steps were taken to try to avoid negative effects on the data. Firstly, using a within subject design requires fewer participants to help increase statistical power (Maxwell and Delaney 2004). This is because each participant serves as his or her control within the experimental design (Gonzalez 2009), in this case the difference between low and high pressure. Secondly, previous studies had found medium effect sizes, for example $R^2 = .30$ (Laborde et al. 2015a; Laborde et al. 2015b) and $f^2 =.0.29$ (Park et al. 2014), which would suggest fewer participants are needed to find an effect. Although sample size is an acknowledged limitation within the current research, it should not take away from the findings of this thesis. It is worth highlighting here the replicability of the regression models explored within the thesis. Babyak (2004) notes that researchers using regression models are interested in finding a combination of variables that reproduce or predict the response of the outcome variable. He goes on to say that “as good scientists we also strive to test the model against a new set of data, collected under different circumstances, to assess how well the results generalize or replicate” (Babyak 2004, p.412). Throughout the thesis the same regression model has been applied to the three separate studies, all of which tested different tasks under high and low pressure. There were three clear areas of replication of results within the data which were found across all three studies such as the positive influence of resting cardiac vagal activity on task and post task cardiac vagal activity. This demonstrates that the model used is a good approximation of the themes found within a portion or sample from the wider population (Babyak 2004). More importantly, this may shape future prediction when examining the same phenomena and therefore advance science and guide future research to look at these themes more closely.

In addition to sample size, limitations in analysis strategy may be highlighted. The thesis implemented hierarchal stepwise regressions as the analysis method across all three studies. Stepwise regressions were deemed suitable for the exploratory nature of model building within this new research area (Field 2009). However, stepwise regression is not without limitation, for example overfitting or under fitting the regression model (Babyak 2004) or the potential for important theoretical variables being excluded because of shared variance (Field 2009). Additionally, the use of two separate stepwise models to examine pressure conditions separately may not be the most valid way of understanding the differences between low and high pressure demands. Future research should look towards using an analysis method that puts both low and high pressure variables within the same model in order to address the interactions with study variables.

There are a wide range of other variables that may influence performance under pressure, that have not been addressed within the present PhD studies. In the thesis variables were selected on their pre-existing relationships with cardiac vagal activity, however there may be many other links that have yet to be explored or that have been explored in line with other variables. For example, the role of cortisol has been shown to affect the performance of a tennis serve, which was also examined in line with trait emotional intelligence (Laborde et al. 2014b). Or variables that may come from other domains for example adverse life events, which have been explored with cardiac reactivity and appraisals under pressure (Moore et al. 2018). Another potential limitation is that the current findings can only be applied to the tasks undertaken. This means that at this current moment knowledge is limited to these relationships within working memory tasks, dart throwing and shooting. It is important to explore this phenomenon in a range of sports and ecological settings to further understand the crossover of findings.

This thesis represents an important step forward in the understanding of the relationships between cardiac vagal activity and coping related variables under pressure that could be strengthened by the limitations addressed. Evidently, further research is needed to provide more detailed examinations, but the current thesis offers a strong foundation for future research to extend upon.

5.7. Future research directions

The findings of this thesis have created new questions and avenues for future research which should continue to combine both psychological and physiological variables. The most significant area for future research is examining the role of the three R's as a consistent framework of measurement and in more research contexts, as suggested by Laborde and colleagues (2017). This systematic application of the three R's will not only strengthen and standardize methodological designs within the field, but help to build new knowledge and theory surrounding self-regulatory processes under pressure. This is paramount to understand how an individual is responding to an event rather than just measuring one time point of heart rate variability, as it has been shown in the current research that recovery can be directly linked to performance outcomes. In line with this, further research should focus on phasic patterns of cardiac vagal activity to understand what pattern is most effective for performance. This could also be combined with a case based approach to understand how practitioners can intervene not only with cardiac vagal activity but how to increase it at the point of stress.

Research should further address the role of stable traits on cardiac vagal activity reactions under pressure, as trait influences on cardiac vagal activity were recurrent throughout all three studies. The role of decision reinvestment in recovery has proved to be a very interesting avenue for future research, given different influences were found according to different pressure conditions. Decision reinvestment has been shown to directly affect performance in decision making specific tasks (Laborde et al. 2015a), however recovery was not measured in this particular study. Athletes often have to make multiple decisions across competitions therefore understanding how this trait may affect recovery could help to influence future performance based research. In line with this, it was clear that some traits had a positive influence on cardiac vagal activity reactions such as self-control. It has been shown in previous research that trait emotional intelligence can be trained (Campo et al. 2016), however training traits and then assessing their effects on psychophysiological reactions under pressure has not been assessed. For example, if trait emotional intelligence self-control increases cardiac vagal activity, as shown in study three, can self-control be trained in athletes to subsequently increase cardiac vagal activity under stress which may in turn positively influence performance. There are many questions that still need to be answered within this domain, and it is hoped that researchers will take on the challenge of understanding these complex psychophysiological relationships.

5.8. Conclusion

This thesis makes a novel contribution to psychophysiology and sport psychology at three levels: theoretical, methodological and applied. At the theoretical level, the current research extends the neurovisceral integration model by demonstrating that cardiac vagal recovery can predict reactions to performance outcome above resting cardiac vagal activity (Thayer et al. 2009). In addition, theory has been advanced through applying the predictions of the model to tasks that are not solely linked to executive function and demonstrating the role of phasic cardiac vagal activity in performance prediction. In line with this finding it is suggested that cardiac vagal activity patterns are examined on a case by case and situational basis for future research. For the first time, cardiac vagal activity and coping related variables have been systematically explored across three performance types under low and high pressure. This demonstrated the need to combine trait and physiological variables as it showed that trait coping related variables affect cardiac vagal activity patterns under pressure. This highlights the need to combine psychological variables with physiological variables to examine the underlying psychophysiological processes that occur under pressure.

From a methodological standpoint, the systematic application of the three R's model throughout the studies in this thesis has promoted a process of standardizing cardiac vagal activity research (Laborde et al. 2017). In applying this method, it was shown that the use of phasic cardiac vagal activity measures allows for further understanding of the complex adaptation and self-regulatory patterns that exist at the psychophysiological level across pressure conditions and differing task demands. This allowed for a better understanding of what psychophysiological processes happen across a pressurised event, from both single time points (tonic) to adaptation (phasic) (Laborde et al. 2017). It is hoped from the findings of this thesis that the three R's model will shape the future of cardiac vagal activity research and demonstrate the importance of using multiple measures in order to understand performance under pressure.

At the applied level this thesis offers practical suggestions directed towards the awareness of individuals' traits and the effects of performance on psychophysiological recovery. The findings from the thesis suggested that traits influence cardiac vagal activity under pressure and should be considered by practitioners as a potential means of manipulating cardiac vagal activity. Moreover, it was shown that in sport specific arenas performance outcome can directly affect cardiac vagal recovery. This finding allows practitioners an intervention opportunity to optimize recovery through mechanical methods such as slow paced breathing (Lehrer 2007), to ensure the athletes are prepared to face the next stressor in the best psychophysiological state.

In summary, this thesis has made a significant and original contribution to the understanding of how pressure influences psychophysiological reactions, how coping related variables contribute to those reactions and uncovering the combinations of subjective and objective measures that can influence performance. The key message delivered in this thesis is that cardiac vagal activity is an invaluable measure to help understand performance under pressure and can be directly influenced by coping related variables.

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7. APPENDIX

Appendix One: Instructional scripts and pressure manipulation development

Study one: Working memory task

Low Pressure Condition
We will shortly ask you to perform a competitive working memory task which is a test of cognitive functioning. This test has been specifically designed to reflect mental ability and it is very important that you try your best to gain the best possible score. During the test your performance will be displayed in the top right hand corner of the screen and should remain above 85% accuracy. Your scores from both sessions will be totalled and once all participants have competed in both sessions your scores will be added to the final leader board which will be emailed to all participants and displayed on a notice board at the University. The top five performers will be awarded cash prizes of £50, £25, £20, £15, and £10, respectively. The worst five performers of today's task will be interviewed by a working memory specialist, the content of which will be based around your understanding of the task, strategy used and decision making. The upcoming working memory task can be difficult and you will have to work very hard in order to perform to a high standard.

Remember we are assessing your working memory which is a competitive task so you must try hard to be as fast as you can. In order to be successful you will have to perform the test as quickly as possible whilst making the fewest mistakes. Your performance today will count towards the final results from which the winners and prize money will be decided; therefore you need to perform to your best. With these instructions in mind you may start the task.

High Pressure Condition
We will shortly ask you to perform a competitive working memory task which is a test of cognitive functioning. This test has been specifically designed to reflect mental ability, with higher scores reflecting greater intelligence. This is the most important part of the experiment and it is very important that you try your best to gain the best possible score. During the test your performance will be displayed in the top right hand corner of the screen and should remain above 85% accuracy. Your scores from both sessions will be totalled and once all participants have competed in both sessions the final leader board will be emailed to all participants and displayed on a notice board at the University. The top five performers will be awarded cash prizes of £50, £25, £20, £15, and £10, respectively. The worst five performers of today's task will be interviewed by a working memory specialist, the content of which will be based around your understanding of the task, strategy used and reasons for poor performance. In addition your performance today will be compared to an international database of sports students who have undertaken the same task. Today, your performance will be recorded on a digital video camera and displayed live to you. It will be analysed by expert psychologists, and may be used in the future to aid teaching on successful and unsuccessful working memory performance. In addition, today a second experimenter will closely observe your facial and behavioural reactions to the task and write down their observations and also analyse the video recording after the task. The upcoming working memory task can be difficult and you will have to work very hard in order to perform to a high standard.

Remember we are assessing your working memory which is a competitive task so you must try hard to be as fast as you can. In order to be successful you will have to perform the test as quickly as possible whilst making the fewest mistakes. Your performance today will count towards the final results from which the winners and prize money will be decided; therefore you need to perform to your best. With these instructions in mind you may start the task.

Study Two: Dart task

Low Pressure Condition
We will shortly ask you to perform a competitive dart throwing task which is a test of psychomotor functioning. This test has been specifically designed to reflect mental and physical ability and it is very important that you try your best to gain the best possible score. During the test your performance will monitored by the experimenter. Your scores from both sessions will be totalled and once all participants have competed in both sessions your scores will be added to the final leader board which will be emailed to all participants and displayed on a notice board at the University. The top five performers will be awarded cash prizes of £50, £25, £20, £15, and £10, respectively. The worst five performers of today's task will be interviewed by a darts expert, the content of which will be based around your understanding of the task, strategy used and decision making. The upcoming dart task can be difficult and you will have to work very hard in order to perform to a high standard.

Remember we are assessing your dart throwing ability which is a competitive task so you must try hard to be as fast as you can. In order to be successful you will have to perform the test as quickly as possible whilst making the fewest mistakes. Your performance today will count towards the final results from which the winners and prize money will be decided; therefore you need to perform to your best. With these instructions in mind you may start the task.

High Pressure Condition
We will shortly ask you to perform a competitive dart throwing task which is a test of psychomotor functioning. This test has been specifically designed to reflect mental and physical ability, with higher scores reflecting greater athletic ability. This is the most important part of the experiment and it is very important that you try your best to gain the best possible score. During the test your performance will monitored by the experimenter. Your scores from both sessions will be totalled and once all participants have competed in both sessions the final leader board will be emailed to all participants and displayed on a notice board at the University. The top five performers will be awarded cash prizes of £50, £25, £20, £15, and £10, respectively. The worst five performers of today's task will be interviewed by a darts expert, the content of which will be based around your understanding of the task, strategy used and reasons for poor performance. In addition your performance today will be compared to an international database of sports students who have undertaken the same task. Today, your performance will be recorded on a digital video camera. It will be analysed by expert psychologists, and may be used in the future to aid teaching on successful and unsuccessful dart throwing performance. In addition, today a second experimenter will closely observe your facial and behavioural reactions to the task and write down their observations and also analyse the video recording after the task. The upcoming dart throwing task can be difficult and you will have to work very hard in order to perform to a high standard.

Remember we are assessing your dart throwing ability which is a competitive task so you must try hard to be as fast as you can. In order to be successful you will have to perform the test as quickly as possible whilst making the fewest mistakes. Your performance today will count towards the final results from which the winners and prize money will be decided; therefore you need to perform to your best. With these instructions in mind you may start the task.

Study three: Shooting task
Low pressure condition
You are about to perform a competitive shooting test which is an analysis of technical and physical functioning. In this competitive trial you will fire ten shots in a 5 minute time frame.
This test has been specifically designed to reflect shooting ability and it is very important that you try your best to gain the best possible score. Once all participants have competed the final leader board will be emailed to all participants. Your scores from both trials will be totalled and the top five performers will be awarded cash prizes of up to £50 for successful performance. The worst five performers of the test will be interviewed by a shooting coach, the content of which will be based around your understanding of the test, strategy used and shot accuracy. The upcoming shooting test can be difficult and you will have to work very hard in order to perform to a high standard. Remember we are assessing your shooting performance which is a competitive test so you must try hard to be as fast and as precise as you can. In order to be successful you will have to perform the test as quickly as possible whilst being as accurate as possible. Your performance in this trial will count towards the final results from which the superior performers will be decided; therefore you need to perform to your best.

With these instructions in mind please wait for the command to start.

High pressure condition
You are about to perform a competitive shooting test which is an analysis of technical and physical functioning. In this competitive trial you will fire ten shots in a 5 minute time frame. In addition any shots scoring below an 8 will be scored as zero and the 10th and final shot will be worth double points. This test has been specifically designed to reflect technical shooting ability, with higher scores reflecting superior performers. This is the most important part of the experiment and it is very important that you gain the highest score you can. Once all participants have competed in both sessions the final leader board will be emailed to all participants and the results from this trial will be published on the NSRA website. Your scores from both trials will be totalled and the top five performers will be awarded cash prizes of up to £50 for superior performance. The worst five performers of the test will be interviewed by a shooting coach, the content of which will be based around your understanding of the test, strategy used and reasons for poor performance. Your performance today will also be compared to an international database of shooting athletes who have undertaken the same test. Your performance in this trial will be recorded on a digital video camera which will be analysed by national level shooting coaches after the test. In addition, the experimenter will closely observe your ability, facial expressions and behavioural reactions to the test and write down their observations. The upcoming shooting test can be difficult and you will have to work very hard in order to perform to a high standard. Remember we are assessing your shooting performance which is a competitive test so you must try hard to be as fast and as precise as you can. In order to be successful you will have to perform the test as quickly as possible whilst being as accurate as possible. Your performance today will count towards

the final results from which the superior performers will be decided; therefore you must perform to your best.

With these instructions in mind please wait for the command to start.

Pressure manipulation development to facilitate an overarching methodological design			
Manipulation	**Proposed Outcome(s)**	**Application**	**Underpinning**
Ego-relevance	Pressure inducement	Instructional script content: "This test has been specifically designed to reflect athletic ability… with greater scores reflecting higher athleticism"	By introducing an evaluative factor into the task it helps to induce pressure (Baumeister and Showers 1986). As the participants will be involved in sport, the threat of the score reflecting athleticism would presumably elicit higher effort and pressure as it reflects an aspect of the self.
Effort mobilization	Motivated performance Recognition of task importance	Instructional script content: "This is the most important part of the experiment and it is very important that you try your best to gain the best possible score" Instructional script content: "Remember we are assessing your… which is a competitive task so you must try hard to be as fast as you can"	Baumeister and Showers (1986) suggest that performance decrements can only be considered as a result of pressure if the participant is motivated to perform well. Therefore, it is important to motivate the participant and reminders are used to ensure effort is directed towards the task. This has been used within sports performance research (Laborde et al. 2014b; Moore et al. 2013; Moore et al. 2012) and following this a manipulation check is will be used to determine whether the participant was motivated to take part.
Competition Ego-relevance	Pressure inducement Explicit competition Social comparison	Instructional script content: "Once all participants have competed in both sessions the final leader board will be emailed to all participants and displayed on a notice board at the University" Instructional script content: "(your performance)...may be used in the future to aid teaching on successful and unsuccessful performance"	Explicit competition occurs when participants are directly informed that their performance will be compared with others (Baumeister and Showers 1968). It is a commonly used method of inducing pressure and has been successfully used in a variety of studies (Laborde et al. 2015b; Turner et al. 2013). As well as comparison with other participants, the results are often made public, which in theory increases the levels of comparison a participant feels.

			Many studies use publically displayed leader boards (Laborde et al. 2015b; Turner et al. 2013).
Performance contingent reward (monetary)	Pressure inducement Motivated performance	Instructional script content: “Your scores from both sessions will be totaled and the top five performers will be awarded cash prizes of £50, £25, £15 and £10 and £5 respectively” Experimental cue: Real monetary reward	When rewards are directly related to the performance of the individual the need to perform well increases which in turn constitutes pressure (Baumeister and Showers 1968). Monetary rewards have been used to induce pressure and strengthen motivation toward tasks within pressure research (Moore et al. 2012; Feinberg and Aiello 2010). Baumeister 1984, experiment 5) found that those who had a monetary reward performed worse than those who did not. Monetary rewards have shown to increase speed within laboratory tasks (Mir et al. 2011; Veling and Aarts 2010), which could indicate an increase in conscious effort towards the task.
Punishment	Pressure inducement Distraction	Instructional script content: “The worst five performers of today’s task will be interviewed by a… performance coach, the content of which will be based around your understanding of the task, strategy used and reasons for poor performance” Experimental cue: Verbal feedback when the participant is performing poorly i.e. “you are not reaching the required standards for this test, please work harder.”	Pressure has been suggested to manifest from threats of punishment as it becomes more important to do well when there is a potential punishment (Baumeister and Showers 1986). An example of the current method is taken from Moore et al. (2012) who used punishment through interviews for those participants who performed poorly.
Filmed performance	Distraction Evaluation apprehension Self-focus	Instructional script content: “Your performance will be recorded on a digital video camera. It will be analysed by expert psychologists, and may be used in the future to aid teaching on successful and unsuccessful reaction time performance”	The presence of a video camera is a commonly used method within pressure research in order to induce pressure (Laborde et al. 2015b; Moore et al. 2012; Turner et al. 2012; Beilock and Carr 2001; Masters 1992; Baumeister 1984).

		Experimental cue: Physical presence of video camera	
Audience presence	Distraction Evaluation apprehension	Instructional script content: "In addition, today a second experimenter will closely observe your facial and behavioural reactions to the task and write down his\her observations and also analyse the video recording after the task" Experimental cue: Physical presence of second experimentor who actively takes notes throughout.	The presence of an audience provokes the individual to be concerned with how the audience perceives him rather than their own performance (Baumeister 1984). Laborde and colleagues (2014b) used the presence of a second experimenter who actively made notes throughout the performance of the task and was used to induce evaluative audience pressure. The same method will be implemented within the current research.
N.B. It is important to note that each individual study had minor alterations in order to make the pressure manipulations specific to the task at hand. This included changes in wording but also task dependent factors such as missing the board in dart throwing, or scoring less than a seven in shooting (please see scripts for individual changes).			

Appendix Two: An example of a recruitment poster

Do you want to win up to **£50** in **CASH** - just by taking a memory challenge?

Bournemouth University

The Centre for Event and Sport Research at Bournemouth University is running an innovative project exploring the use of cardiac reactivity during a memory challenge.

For the best performers there will be cash prize of up to £50.

We require both males and females who actively participate in sport.

Psychology students this study is worth 1.5 credits

So, if you want to take part, email your name and telephone number to:

Emma Mosley– emma.mosley@bournemouth.ac.uk

Appendix Three: Study resource examples (information sheet, informed consent, testing questionnaires, debrief sheets)

Participant Information Sheet

Working Memory and Heart Reactivity Study
You are being invited to take part in a research project. Before you decide to participate it is important that you understand the study and what is involved. Please read the following information carefully and if anything is unclear feel free to ask for more information.

What is the purpose of the study?
This study aims to determine the changes in heart reactivity that happen during a working memory task under two different competitive settings. Working memory is your capability to retain information whilst completing other tasks. Therefore from this study we aim to understand how our heart reacts during performance of a cognitive task. This helps to understand how both physical and mental processes affect the performance of athletes.

Why have I been chosen?
You have been chosen because you are an athlete actively competing in sport. As this study focuses on performance in competitive settings it is important to use individuals who are used to competing.

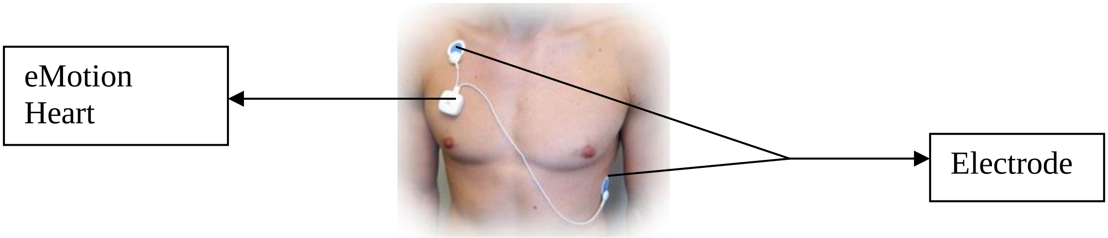
It is up to you to decide whether or not to take part. If you do decide to take part you will be given this information sheet to keep (and be asked to sign a consent form) and you can still withdraw up to the point of data analysis. You do not have to give a reason. In the case of health and social care, deciding to take part or not will not impact upon/adversely affect your (or that of others) education.

What do I have to do as a participant?
Before the session

- Complete the online questionnaires that will be emailed to you before you come to the lab for practical testing. These are two sets of questionnaires that take approximately 30-40 minutes per questionnaire.
- Refrain from drinking alcohol and strenuous exercise at least 24 hours before participation.
- At least two hours before participation please refrain from drinking caffeine or smoking.
- Be aware that you need to attend two performance sessions each lasting 30 minutes. Two sessions are needed as working memory will be assessed under two different competitive conditions similar to those faced by athletes in competition.

During the session

- When you arrive you will be given a brief introduction to the experiment.
- Then you will have two disposable electrodes attached to your torso. They involve being stuck onto the skin and may involve minor discomfort during removal, **see picture below**.



- Then you will compete in a working memory task in which you have to make the fewest mistakes to win. Your final score will be a combination of the scores in both sessions which means it is very important that you attend both sessions.
- For one of the sessions your performance will be filmed. The video recordings of your activities made during this research will be used only for analysis and no other use will be made without your permission
- Once set up you will participate in working memory task whilst your heart reactions are being measured.

- *After the session*
- Electrodes are removed and you are thanked for your participation and informed of your next session.
- All the information that we collect about you during the course of the research will be kept strictly confidential. You will not be able to be identified in any reports or publications.

What are the benefits and disadvantages of participating?

Whilst there are no immediate benefits for those people participating in the project, it is hoped that this work will aim to better the understanding of mental and physiological functioning under a competitive cognitive task.

Some disadvantages may include the time given by the participant in the prolonged testing i.e. having to attend two sessions and answer lengthy questionnaires. Another may be the minor discomfort when removing the electrodes.

Finally…

Remember, your participation in this study is voluntary and you may withdraw from the study at any point. Please note that withdrawal from this study will not affect any future grades at the University. You will be given a copy of this information sheet and a consent form to keep for your own records. If you have any questions in relation to the study they can be answered through email. Thank you for taking the time to read this information sheet.

Contact for further information

Emma Mosley
Email: emma.mosley@bournemouth.ac.uk Phone: 01202 965046

In the event of a complaint please contact:

Prof Stephen Page, Deputy Dean – Research
Email: spage@bournemouth.ac.uk Phone: 01202 962306

Consent to Participation: Working Memory and Heart Reactivity Study

If you have read the information sheet and have decided to participate in this experiment please **read the following information carefully**. Your participation in this study is voluntary and you have the right to withdraw your consent or discontinue participation at any time up until your anonymous performance data has been analysed. If you choose not to participate in this study there will be no repercussions or effects on any future University grades. Your individual privacy and anonymity will be maintained at all times including all published and written data resulting from the study.

Please tick to confirm that you meet the following conditions:	Yes	No
Have you read the information sheet and consent form, understood it and agree to it?		
Can you confirm you have *no known* heart or respiratory conditions?		
Can you confirm you have *no known* allergy to electrode gel?		
Can you confirm you have *not* done any strenuous exercise in the past 24 hours?		
Can you confirm you have *not* consumed alcohol in the past 24 hours?		
Are you a smoker? *If yes how many cigarettes do you smoke a day* ______________________________		
In the past two hours you have *not* smoked?		
In the past two hours you have *not* consumed caffeine?		
In the past two hours you have *not* eaten?		
Are you taking any medication? If yes what medication/s are you taking ______________________________________		
For female participants, are you taking a form of oral contraceptive?		
Did you follow your usual sleep routine last night? Bed Time_______________________ Waking Time_______________________		
Do you suffer from any mental disorders, for example severe depression or anxiety disorder?		
Do you need to use the bathroom?		
Have you rushed in order to arrive on time for this experiment?		

If you agree with the above-stated conditions and are willing to participate in the experiment, please sign below.

Participant Name:___________________________________

Date:____________

Email____

Signature:____

If you have any questions during the study please do not hesitate to ask and any further questions in relation to any aspect of the study can be answered through email or phone.

Thank you for your participation in this study.

Email: emma.mosley@bournemouth.ac.uk Phone: 01202 965046

In the event of a complaint please contact: Prof Stephen Page, Deputy Dean – Research

spage@bournemouth.ac.uk Phone: 01202 962306

Testing Questionnaires

1

1) On the line below please put a cross indicating how stressed you feel at this moment.

Not at all stressed	Extremely stressed

2

2) On the line below please put a cross indicating how stressed you feel at this moment.

Not at all stressed	Extremely stressed

3

On the line below please put a cross indicating how stressed you feel at this moment.

Not at all stressed	Extremely stressed

WM ABSOLUTE SCORE:

Below you will find questions that describe a range of feelings. Please read each one carefully and indicate on the scale next to each item how you felt during the working memory task. There are no right or wrong answers. Do not spend too much time on any one item, but choose the answer which best describes your feelings during the working memory task.

1) On the line below please put a cross indicating how stressed you feel at this moment.

Not at all stressed ◆————————————◆ Extremely stressed

2) On the lines below please put a cross indicating where your attention was focused during the task.

Towards the task ◆————————————◆ Away from the task

Towards self ◆————————————◆ Away from self

3) Answer the following questions in the grids according to the relevant scoring scale.

	Not at all ←				→ Extremely
How demanding did you feel the working memory task was?	1	2	3	4	5	6
How able were you to cope with the demands of the working memory task?	1	2	3	4	5	6

	Strongly Disagree	Disagree	Somewhat disagree	Neither disagree or agree	Somewhat agree	Agree	Strongly Agree
I felt tense while doing the working memory task.	1	2	3	4	5	6	7
I felt pressured whilst doing the working memory task.	1	2	3	4	5	6	7
I was anxious whilst doing the working memory task.	1	2	3	4	5	6	7
I was very relaxed whilst doing the working memory task.	1	2	3	4	5	6	7

	Not at all	A little	Somewhat	Moderately	Quite a bit	Very much so
How motivated were you to perform to your best in this task?	0	1	2	3	4	5

Debrief for Heart Reactivity and Working Memory Study

Thank you for participating in the study.
You will be notified when you are needed for the second session of the study.
Please refrain from telling others the content of the study as this may impact future results.
If you have any complaints, concerns, or questions about this research, please feel free to contact: Emma Mosley: emma.mosley@bournemouth.ac.uk

Final Debrief and Post-Test Consent Form

Firstly, thank you for giving up your time to take part in this research study. I hope that it has proved an interesting test of your skills and abilities.

The reason for this form is to outline the underlying aims of this research project and why you competed in the environment that was set up. The research aimed to:

- Understand how sport students performed under pressurized situations. You competed twice – once in a low pressure condition and once in a high pressure condition. This was to understand the differences in performance in these environments.
- Understand how personality factors affect performance under pressure. In completing the questionnaires before the pressure test we are able to understand your personality and how it related to your subsequent performance under pressure.
- Gain a measure of stress during pressure testing. You were wired up to a heart rate monitor so we could track the changes in your heart rate. This allows us to understand how stressed you were during the pressure test.

After reading the final debrief information can you confirm that (please tick to confirm):

☐ You understand the true nature of the study and why it was carried out.
☐ You are happy for your anonymous individual data from this study to be used for publishing and further research.

If you agree with the above-stated conditions please sign below.

Participant Name:____
Date:______________
Email____
Signature:____

If you have any further questions in relation to any aspect of the study these can be answered through email, please to not hesitate to ask. **Thank you for your participation in this study.**
Emma Mosley: emma.mosley@bournemouth.ac.uk

Appendix Four: Dart throwing instructions

Dart throwing instructions

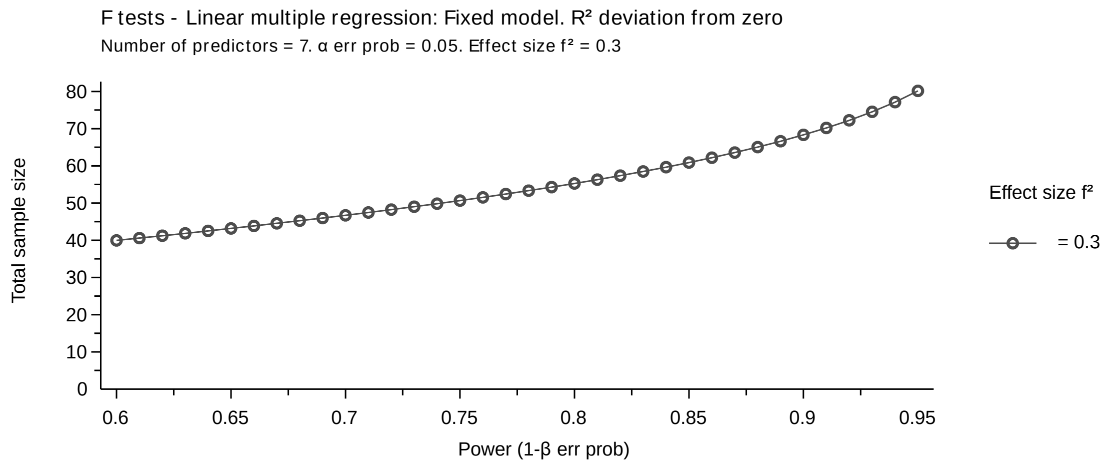
1) Place feet behind the throwing line. You may want to have the corresponding foot to your throwing hand slightly forward.
2) Stand up straight in line with the board.
3) Hold the dart like a pencil and use a light grip.
4) Focus on the area of the dart board as a target.
5) Bring the dart back towards your ear in a level position.
6) Throw the dart ensuring your only move your throwing arm. Avoid using a flicking or jerking motion or a great deal of force. Only move your throwing arm and avoid using a whole body action.

Participant proceeds to have 24 familiarization throws.
Adapted from: http://www.wikihow.com/Throw-Darts

Appendix Five: Sample size modelling calculations (both *a priori* and *posteriori*)

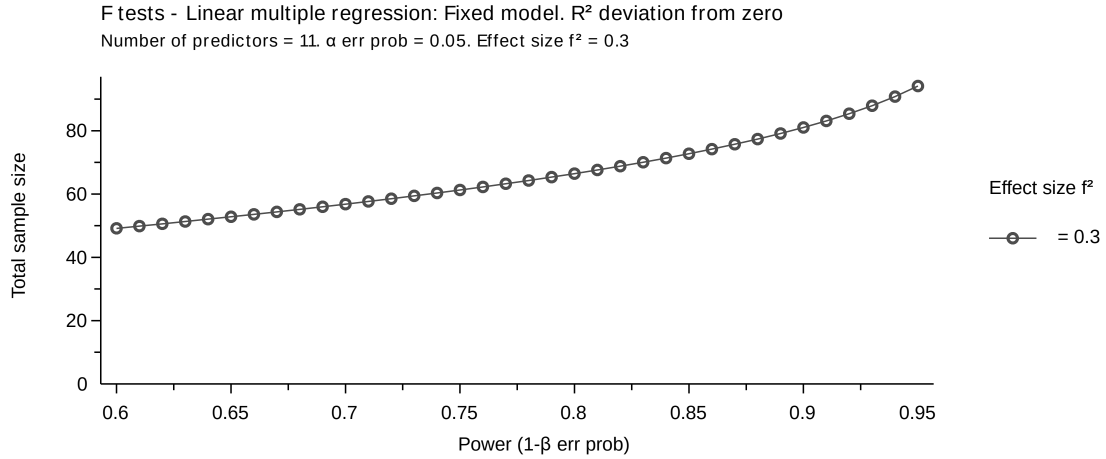
The following plots demonstrate sample size calculations for each separate regression model that were tested across all three studies. Both *a priori* sample size calculations which were done prior to the studies commencing and *posterori* analysis to demonstrate power and effect sizes possible with the sample collected.

Resting CVA:
Independent variables: Trait EI (global, emotionality, sociability, wellbeing, self control), Reinvestment (movement and decision) = 7 predictors



Study	Sample	A priori Sample required for .80	A priori power (with sample collected)	Posteriori analysis effect size (with sample collected)
Working memory	49	56	.73	.35
Darts	51	56	.75	.33
Shooting	38	56	.57	.47

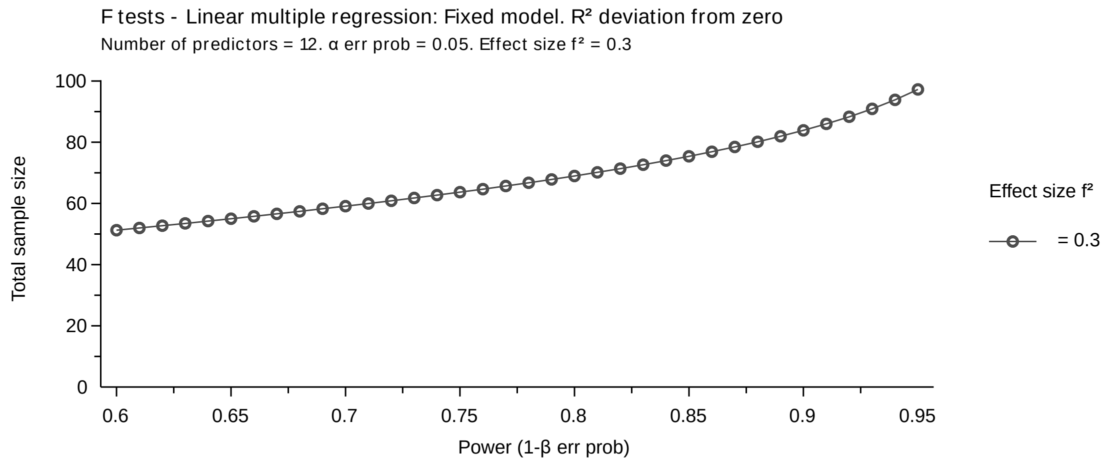
Task CVA:
Independent variables: Trait EI (global, emotionality, sociability, wellbeing, self control), Reinvestment (movement and decision), attention (task, self), challenge and threat ratio, resting CVA = 11



Study	Sample	A priori Sample required for .80	A priori power (with sample collected)	Posteriori analysis effect size (with sample collected)
Working memory	49	67	.60	.44
Darts	51	67	.63	.42
Shooting	38	67	.43	.62

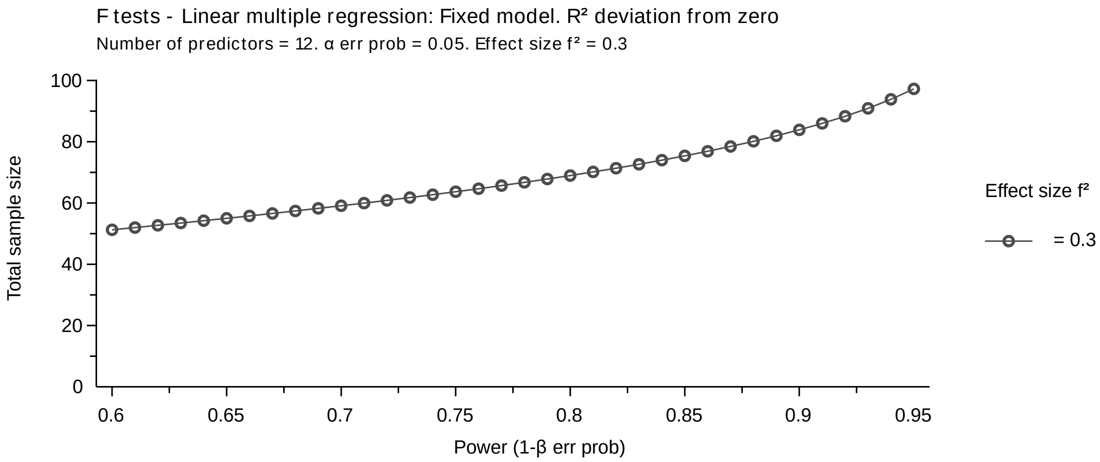
Post task CVA:

Independent variables: Trait EI (global, emotionality, sociability, wellbeing, self control), Reinvestment (movement and decision), attention (task, self), challenge and threat ratio, resting CVA, task CVA = 12



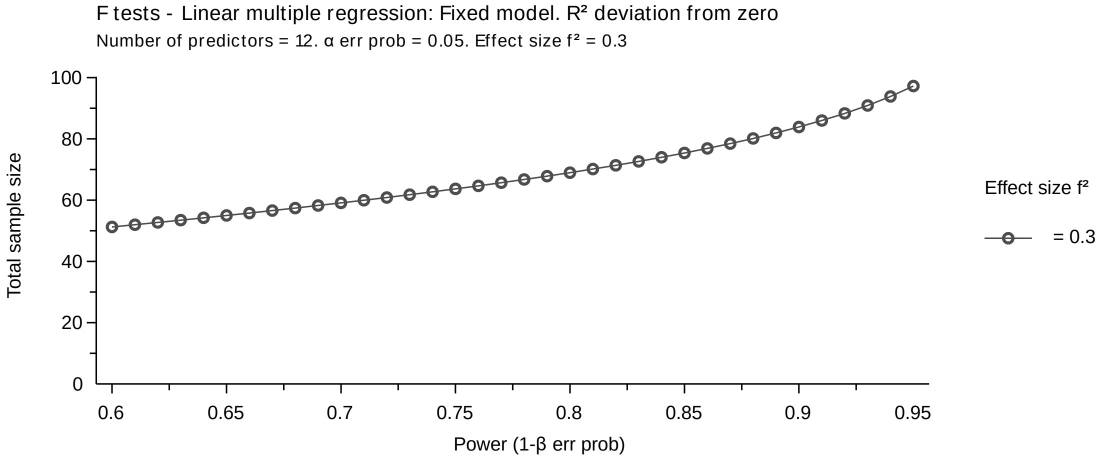
Study	Sample	A priori Sample required for .80	A priori power (with sample collected)	Posteriori analysis effect size (with sample collected)
Working memory	49	69	.57	.46
Darts	51	69	.60	.44
Shooting	38	69	.40	.66

Reactivity CVA:
Independent variables: Trait EI (global, emotionality, sociability, wellbeing, self control), Reinvestment (movement and decision), attention (task, self), challenge and threat ratio, resting CVA = 12



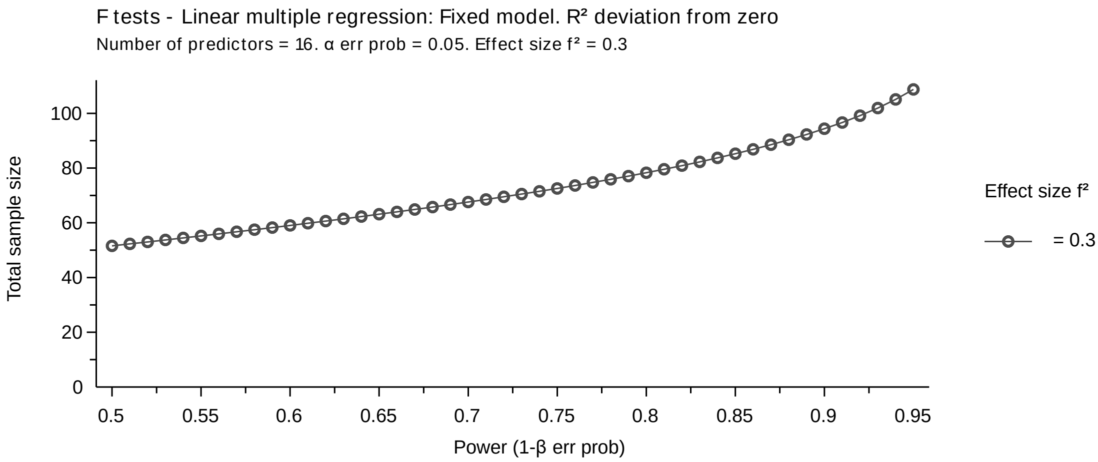
Study	Sample	A priori Sample required for .80	A priori power (with sample collected)	Posteriori analysis effect size (with sample collected)
Working memory	49	69	.57	.46
Darts	51	69	.60	.44
Shooting	38	69	.40	.66

Recovery CVA: Trait EI (global, emotionality, sociability, wellbeing, self control), Reinvestment (movement and decision), attention (task, self), challenge and threat ratio, resting CVA = 12



Study	Sample	A priori Sample required for .80	A priori power (with sample collected)	Posteriori analysis effect size (with sample collected)
Working memory	49	69	.57	.46
Darts	51	69	.60	.44
Shooting	38	69	.40	.66

Performance: Trait EI (global, emotionality, sociability, wellbeing, self control), Reinvestment (movement and decision), attention (task, self), challenge and threat ratio, resting CVA, task CVA, post task CVA, Reactivity CVA, Recovery CVA = 16



Study	Sample	A priori Sample required for .80	A priori power (with sample collected)	Posteriori analysis effect size – F2 (with sample collected)
Working memory	49	79	.46	.56
Darts	51	79	.49	.53
Shooting	38	79	.30	.85

Appendix Six: Publications related to the thesis

This thesis includes a number of sections that are published in the form of journal articles, book chapters and conference papers. The details of all outputs related to this thesis are as follows:

Journal Articles

Mosley, E., Laborde, S., Kavanagh, E., 2018. The contribution of coping related variables and cardiac vagal activity on prone rifle shooting performance under pressure. *Journal of Psychophysiology*, 1-17.

Mosley, E., Laborde, S., Kavanagh, E., 2018. The contribution of coping related variables and cardiac vagal activity on working memory performance under pressure. *Acata Psychologica*, 191, 179-189.

Mosley, E., Laborde, S., Kavanagh, E., 2017. The contribution of coping related variables and cardiac vagal activity on the performance of a dart throwing task under pressure. *Physiology and Behavior, 179,* 116-125.

Book chapters

Mosley, E. and Laborde, S., 2016. Performing Under Pressure: The Influence of Personality-Trait-Like Individual Differences. *In:* Raab, M., Lobinger, B., Hoffmann, S., Pizzera, A. and Laborde, S., 2016. Performance Psychology: A Scientific Guide across Perception, Action, Cognition and Emotion. UK: Esliever.

Mosley, E., and Laborde, S., 2015. Performing with all my Heart: Heart Rate Variability and its Relationship with Personality-Trait-Like-Individual-Differences (PTLIDs) in Pressurized Performance Situations. *In:* Walters, S., 2015. Heart Rate Variability (HRV): Prognostic Significance, Risk Factors and Clinical Applications. USA: Nova Biomedical.

Conference papers

Mosley, E., Laborde, S., and Kavanagh, E., 2017. The contribution of coping related variables and cardiac vagal activity on prone rifle shooting performance under pressure. *Journal of Sport Sciences*, 34 (1), 10-11. Presented at the BASES Conference, Nottingham, England.

Mosley, E., Laborde, S., and Kavanagh, E., 2017. The contribution of coping related variables and vagal tone on working memory performance under pressure. Presented at the International Congress for Sport Psychology, Seville, Spain.

Mosley, E., Laborde, S., and Kavanagh, E., 2017. The contribution of coping related variables and vagal tone on dart throwing performance under pressure. Presented at the International Congress for Sport Psychology, Seville, Spain.

Mosley, E., Laborde, S., and Kavanagh, E., 2016. Preliminary results of the contribution of coping related variables and vagal tone on dart throwing performance under pressure. *Journal of Sport Sciences*, 34 (1), 10-11. Presented at the BASES Conference, Nottingham, England.

Mosley, E., and Laborde, S., 2015. Personality-trait-like individual differences and their influence on performance under pressure: A review. Presented at the European Conference of Sport Psychology (FEPSAC). University of Bern, Switzerland.