ANGLIA RUSKIN UNIVERSITY

FACULTY OF SCIENCE AND TECHNOLOGY

THE INFLUENCE OF STRESS ON VISUAL ATTENTION AND PERFORMANCE EXECUTION IN AIMING TASKS

KJELL VAN PARIDON

A thesis in partial fulfilment of the requirements of Anglia Ruskin University for the degree of Doctor of Philosophy

Department of Sport and Exercise Sciences

Submitted: January 2018

Acknowledgements

There are many people I would like to thank for their help throughout this journey. I would like to acknowledge the continuous support from the Faculty of Science and Technology and Department of Sport and Exercise Sciences in making it possible to complete this thesis. A special thank you should go to my supervisors Mat Timmis, Matt Bristow and Charlie Nevison. Your scientific guidance and dedication of time made this an enjoyable journey. More importantly, you managed to keep me on track and did not let me drift off towards all the other fun things that can be investigated. Mat, it has been a privilege to share an office with you over the years. I’m grateful for all the colleagues who helped me throughout the years by providing technical, intellectual and social support.

Finally, I would like to thank Esther, Kalle, Tabe, my parents and sister. Thank you for your encouragement and patience, most importantly, thank you for being supportive in every decision I made in life.

ANGLIA RUSKIN UNIVERSITY

ABSTRACT

FACULTY OF SCIENCE AND TECHNOLOGY

DOCTOR OF PHILOSOPHY

THE INFLUENCE OF STRESS ON VISUAL ATTENTION AND PERFORMANCE EXECUTION IN AIMING TASKS

KJELL VAN PARIDON

January 2018

This thesis examines the endocrine response in naturalistic sport environments and laboratory based stress manipulations to investigate the role of anxiety and biological stress on visual search behaviour and movement execution in perceptual-motor skills.

The first study, a systematic review with meta-analysis, identified that athletes experience a significant cortisol response in anticipation to sport competition. Moderator analysis identified that females and athletes competing at international level do not demonstrate this anticipatory cortisol response. Study two, a validation of a golf putting task with a pressure manipulation including self-presentation and performance contingent motivational stimuli, identified distinct inter-individual differences in HPA-axis reactivity, in contrast to SNS reactivity. Responders demonstrated a significant increase in cortisol, in magnitude comparable to real sport competitions, where this was absent in non-responders. Non-significant correlations were found between endocrine reactivity and self-reported measures of anxiety, supporting previous research of the independence of the biological and emotional stress response.

The effects of anxiety and endocrine reactivity on performance, visual attention and movement execution in a golf putting task were examined in study three and four. Study three identified that performance accuracy significantly improved under high pressure compared to low pressure. This improvement in performance was explained by a significant reduction in visual attention towards task-irrelevant stimuli and reduced variability in the club head angle at ball impact. Study 4 explored the effects of inter-individual differences in endocrine reactivity on the underlying processes of golf putting performance. Participants with high levels of cortisol were significantly less accurate in performance outcome compared to participants with low cortisol. A significant increase in visual attention towards task-irrelevant stimuli in participants with high cortisol, provided support for the influence of cortisol on the stimulus-driven attentional system in executing perceptual-motor skills under pressure.

The interdisciplinary approach in the examination of stress and anxiety on sport performance suggests that both anxiety and cortisol reactivity effects sport performance through its influence on visual attention and movement execution. The inter-individual differences in cortisol reactivity and its effect on movement execution and visual attention, warrants further investigation.

Key words: anxiety, cortisol, sAA, BPSM, visual attention, sport performance, movement execution

Table of Contents

List of Figures

List of Tables

COPYRIGHT DECLARATION

Chapter 1: Literature review

1.1 Background

"*Everyone expected him to succeed, no matter what the arena, and so failure, even temporary failure, had ceased to be an option*." (Chad Harbach, The Art of Fielding)

The above quote comes from the fictitious story about Henry Skrimshander, a rising star pitcher in college baseball, whose anxiety and self-doubts about his pitching ability, resulted in egregious performance. Although a fictitious story, its plot draws on examples of elite athletes losing their ability to perform successfully under high pressure conditions. Indeed, on occasions the pressure surrounding sport competition results in dramatic performance decrements. For example, the Dutch bobsleigh pilot, Edwin Calker, refused to steer his bobsleigh during the 2010 Vancouver Winter Olympics because of his angst to crash, where Jana Novotna suffered a catastrophic breakdown in the Wimbledon tennis final of 1993 (e.g., Novotna lost after securing a 4-1 lead in the final set). In contrast to performance decrements, it is more common that athletes are able to retain their composure and perform optimally under pressure (although not regularly highlighted in the media). Danny Willett's "nerveless manner in which he played the last two holes" to secure a win at the US masters in 2016, compared to a "painful to watch closing stretch" of Jordan Spieth in the same competition (Murray, 2016) highlights the fascinating differences between athletes who maintain their composure and perform (Otten, 2009) versus a dramatic collapse in performance, commonly identified as choking (Baumeister, 1984), in high pressure situations.

Although it is intuitive to generalise the manifestation of stress in these athletes, the conceptualization of stress from a transactional perspective highlights that the development of stress refers to a dynamic relationship between the environmental demands and the coping resources available to the athlete (Lazarus, 2000). When athletes operate in comparable environments, the personal significance of the situation, referred to as a relational meaning, influences the development of stress. The Dutch bobsleigh pilot, Edwin Calker, started to doubt his ability following a training crash on the bob sleigh course, and fear of harm, following the death of competitor on the same course. Danny Willett held low expectancies of winning the US Masters, where Jordan Spieth was defending his title. These situational differences in personal significances within the appraisal of the dynamic relationship between environmental demands and coping resources, can influence the decision making process (e.g., not competing in Calker's situation) and magnitude of the stress response. In line with the above described process of conceptualizing stress, stress can be defined as "an ongoing process that involves individuals transacting with their environments, making appraisals of the situations they find themselves in, and endeavouring to cope with any issues that may arise" (Fletcher, Hanton, & Mellalieu, 2006). Inherently to the above definition of stress, it highlights that stress, as a process, in itself does not automatically stipulate the development of positive or negative psychological states, as the emotional connotations associated with stress are not specified. Although not specified in this definition of stress, Lazarus (2000) postulates that distinct emotions develop within this process. Where emotions such as pleasure and anger might develop, specifically the emotion of anxiety has been extensively examined in competitive sports (Martens, Vealey, & Burton, 1990). The state of anxiety, in contrast to anxiety as a trait characteristic of personality, is defined by Spielberger as "a negative emotional state characterised by subjective, consciously perceived feelings of apprehension and tension, accompanied by or associated with activation or arousal of the autonomic nervous system" (Spielberger, 1966). Although Spielberger's definition postulates different components of anxiety (e.g., feelings of apprehension and arousal) the psychometric measurement of state anxiety in Spielberger's work reflects a one-dimensional approach. Within sport psychology, anxiety is regarded as having multiple and distinguishable components. A mental component, referred to as cognitive anxiety, can be defined as "negative expectations and cognitive concerns about oneself, the situation at hand, and potential consequences" (Morris, Davis, & Hutchings, 1981). Whereas a physiological component, labelled as somatic anxiety, can be defined as "one's perception of the physiological-affective elements of the anxiety experience, that is, indications of autonomic arousal and unpleasant feeling states such as nervousness and tension" (Morris et al., 1981).

The evaluative process proposed by Lazarus (2000) also forms the foundations of the biopsychosocial model (BPSM, Blascovich & Mendes, 2000) where individuals evaluate the relative demands (e.g., danger, uncertainty) and resources (e.g., abilities and knowledge) of motivated performance situations under high task engagement. The BPSM proposes that when the demands outweigh the resources, the individual will experience a state of threat whereas a state of challenge is experienced when the resources meet or outweigh the demands. Although the factors that influence the development of anxiety, challenge and threat, are commonly examined (Mellalieu, Neil, Hanton, & Fletcher, 2009; Seery, 2013) researchers have particularly focused their attention towards identifying whether anxiety and challenge or threat, affects sport performance and if so, how it affects sport performance. A recent systematic review (Hase, O'Brien, Moore, & Freeman, 2018), including 38 studies examining the effects of challenge and threat states on performance, identified that a challenged state benefits both cognitive and behavioural task performance, in contrast to a threatened state. Likewise, the cognitive and somatic components of anxiety, in combination with self-confidence, formed the basis of theories such as the multidimensional anxiety theory (Martens et al., 1990), which attempted to explain the relationship between anxiety and sport performance. To address this question, two meta-analyses were published (Craft, Magyar, Becker, & Feltz, 2003; Woodman & Hardy, 2003) which examined whether anxiety affects sport performance in naturalistic environments. Craft et al. (2003) assessed whether anxiety and confidence, assessed via the Competitive State Anxiety Inventory (CSAI-2), would explain sport performance based on 29 identified studies. Woodman and Hardy's (2003) analysis, based on 46 studies, addressed whether self-confidence and cognitive anxiety, irrespective of measurement instrument, would explain sport performance. Both meta-analyses identified that self-confidence has the strongest, and positive, relationship with sport performance in contrast to state anxiety components. However, Craft et al. (2003) identified that cognitive and somatic anxiety did not explain sport performance whereas Woodman and Hardy (2003) identified that cognitive anxiety demonstrated to have a negative relationship with sport performance (r=-0.10), albeit with a small effect. These differences can be partially explained by the statistical approach adopted. Craft et al. (2003) corrected for the inter-correlations between constructs of the CSAI-2, which is expected to reduce the explanatory power of the model due to shared variance. Woodman and Hardy (2003) treated the constructs as independent, did not correct for the expected inter-correlation and analysed whether the mean effect size of the cognitive anxiety-performance relationship was different from zero. It is therefore likely that the reported results by Woodman and Hardy (2003) overestimate the effects of cognitive anxiety on sport performance. Although both meta-analyses analysed participant characteristics (e.g., gender), type of sport and measurement procedure, both did not attempt to analyse, categorise, or correct for differences in the measurement of performance within the included studies. Performance measures vary in their sensitivity to describe the quality of the sport performance behaviours (e.g., deviation from personal best or goals scored versus winning or losing). For example, the study by Krane, Williams and Feltz (1992), included in both meta-analyses, used a standardized performance measure in golf, based on a participant's handicap in relation to the performance in a tournament, whereas the included study by Chapman et al. (1997) used an outcome measure of performance (e.g., a win versus a loss). By not controlling for these different performance measures, both meta-analyses missed the opportunity to examine whether differences in performance measures explain the anxiety-performance relationship. Earlier studies, predominantly in laboratory settings, highlight that performance outcome is often not affected by anxiety, however, underlying processes and behaviours that lead to changes in performance outcome, are more likely to be affected (Pijpers, Oudejans, Holsheimer, & Bakker, 2003). To this extent, it is important to highlight the models by Nieuwenhuys and Oudejans (2012) and Vine, Moore and Wilson (2016), which propose that to examine the effects of anxiety on sport performance, a holistic approach is needed. Nieuwenhuys and Oudejans (2012) integrated model of anxiety and perceptual motor performance conceptualises the influence of state anxiety on the perception of information, visual attention and performance execution and outcome. In contrast, Vine, Moore and Wilson (2016) integrative framework of stress, attention, and visuomotor performance is developed on the foundations of the BPSM. The framework proposed by Vine, Moore and Wilson (2016) differentiates between the development of more challenged or threatened states based on the evaluation of demands and resources in stressful situations. Both models share that the effects of a threatened or anxious state influences visual attention and performance execution and outcome. The suggested holistic examination proposed by both models (i.e., Nieuwenhuys and Oudejans, 2012; Vine, Moore and Wilson, 2016) creates more challenges, as the number of variables under examination (e.g., psycho-physiological, visual search behaviour, movement execution) increases. Naturalistic environments do not allow for the examination of these variables, hence studies choose to examine the influence of these variables in laboratory based scenarios where a simulation of a competitive environment is created. However, a challenge with the laboratory setting is the consistent finding that the reported emotions (e.g., anxiety) associated with these environments are lower than reported in real sport competitions. Where studies in the sport psychology domain dominate in the examination of the effects of emotional responses (e.g., state anxiety) on sport performance, considering the psychophysiological responses to stress could provide stronger empirical evidence to explain changes in perceptual-motor performance under stress (Vine et al., 2016).

Additional to the development of distinct emotions in stressful situations, it is also expected to concurrently trigger a biological stress response, through activation of the sympathetic nervous system (SNS) and the hypothalamic-pituitary-adrenal (HPA) axis. Specifically the BPSM (Blascovich & Mendes, 2000) postulates that challenged or threatened states reflects distinct physiological responses through activation of the sympathetic-adrenomedullary system (SAM) of the sympathetic nervous system (SNS) and the hypothalamic-pituitary-adrenal (HPA) axis. BPSM postulates that challenged states results in SNS activation and threat states increases both HPA-axis and SNS activation. Although SNS and HPA-axis activation in relation to challenge and threat is a central feature of the BPSM (Seery, 2013), the BPSM proposes to assess the parasympathetic effects (i.e., cardiovascular responses) of these pathways. However, particularly HPA-axis activation can be assessed directly via cortisol and has independently been linked to sport performance (Casto & Edwards, 2016; Salvador, 2005) even suggesting an inverted-U relationship between HPA-axis activity and sport performance (Lautenbach & Laborde, 2016), referring back to the work of Yerkes and Dodson (1908). Within the psychology domain there is a strong interest to examine inter-individual differences and determinants of the endocrine response in stressful situations (Kudielka, Hellhammer, & Wüst, 2009). Individual studies in the sport domain occasionally examine determinants and inter-individual differences in the endocrine response (Salvador, 2005). However, a systematic review with meta-analysis could clarify the determinants of the endocrine response in the sport setting and for example examine the differences in stress reactivity between different athlete populations (e.g., gender, experience) and enhance our understanding whether the endocrine response in naturalistic environments is comparable to that in simulate, laboratory based environments. This can support, or challenge, the findings that the emotional response is generally lower in a laboratory setting. Additionally, the investigation of the endocrine response in a laboratory settings allows for the examination of the influence of the endocrine response on the underlying mechanism of perceptual-motor skill performance. Although both Nieuwenhuys and Oudejans (2012) and Vine, Moore and Wilson (2016) advocate to examine the effects of anxiety and stress on sport performance at the level of performance outcome, performance execution and visual attention, studies do not regularly examine these variables concurrently. For example, Cooke et al. (2010) examined the effects of anxiety on golf putting performance and movement execution, but did not examine potential mediating effects of visual attention. In contrast, Chamberlain and Hale (2007) examined the effects of anxiety on golf putting performance, where Wilson and Pearcy (2009) examined the effects of anxiety on visual attention in golf putting. To date there are no studies that have combined the effects of anxiety and the endocrine response on performance, performance execution and visual attention. Therefore, the overarching aim of this PhD thesis is to examine the role of both anxiety and endocrine reactivity on visual attention and performance execution in perceptual-motor skills during high pressure conditions. Within a series of studies, the magnitude of the cortisol response in anticipation to sport competition is evaluated and related to the endocrine response in a competitive laboratory environment with self-presentation and motivation stimuli. In addition, the effects of both anxiety and the endocrine response on performance, performance execution and visual attention to task-relevant and irrelevant information is examined. Detailed aims are presented at the end of chapter 1.

1.2 Visual attention in perceptual-motor skills

The performance and successful execution of a motor skill relies on the use of visual information from the environment to prepare for, update and monitor the execution of the skill (Land, 2009). These motor skills, that incorporate the perception and use of sensory information in the coordination of the skill, are referred to as perceptual-motor skills. Within the preparation and execution of these motor skills, athletes are selective in the direction of visual search behaviour to ensure visual attention is directed towards task-relevant information whilst ignoring task-irrelevant information. The process of visually examining the environment (e.g., visual search behaviour) is achieved by combined head and eye movement to ensure that light of the optic array is positioned on the retina. However, visual acuity of the retina is not uniform, the highest resolution image is derived from the central part, the fovea, where the acuity of the image drastically reduces in the periphery of the retina (Williams, Davids, & Williams, 1999). Although peripheral vision can identify the presence and movement of objects, it is the movement of the eyes that can ensure that the fovea is directed towards the object to extract the fine details of this in the environment (Williams et al., 1999). This process, referred to as visual search behaviour, is characterised by short periods of movement of the eyes, saccades, to direct the fovea to a new part of the visual field, and static periods, where the finer detail of that part of the environment is examined. These eye movements can be recorded with eye tracking systems to examine visual search behaviour (i.e., when, what, how often and for how long key information is directed to the fovea). Although overt visual attention can be assessed through the recording of eye movements, research has shown that attention can be shifted without eye movement (i.e., covert attention), highlighting the difference between seeing and perceiving (Posner, 1980). As saccadic eye movements are considered voluntary movements, it is generally accepted that shifts in covert attention are reflected in changes in the direction of gaze (Hayhoe & Ballard, 2005). However, the direction of overt visual attention is considered a two-way process between volitional control, based on task demands, and automatic capture of visual information based on the saliency of stimuli (Buschman & Miller, 2007). The interaction between anatomical brain networks and attentional processes is highlighted in Corbetta and Shulman's (2000) work where it is proposed that overt visual attention is a coordinated interplay between a goal-directed attentional system (top-down) and a stimulus-driven (bottom-up) attentional system (Corbetta & Shulman, 2002). Corbetta and Shulman (2002) highlight that the goal-directed attentional system is involved in using knowledge, expectations and goals in the active selection of task-related stimuli and action responses, a process described as orienting. In contrast, the stimulus-driven attentional system is involved in detecting sensory stimuli that are task-contingent and/or stimuli that are salient or unexpected, a process described as alerting. The interaction between these two networks explains how athletes can maintain their attention on task-relevant information, whilst ignoring task-irrelevant and potentially distracting stimuli. Moreover, the coordination between these two networks also specifies that unexpected or salient task-irrelevant stimuli could interfere with maintaining control on task-relevant information. Although the interaction between the two attentional systems can explain distractor interference during the execution of perceptual motor skills, they also form the basis of theories, such as attentional control theory (ACT, Eysenck, Derakshan, Santos, & Calvo, 2007), that explain the effects of anxiety on these skills (see section 1.6).

1.3 Anxiety and performance: execution focus and distraction models

Evidence from the cognitive psychology domain (Eysenck & Calvo, 1992; Eysenck et al., 2007) and sport science domains (Beilock & Gray, 2007; Janelle, 2002; Wilson, 2008) suggest that anxiety affects both the efficiency as well as the direction (i.e., to task-relevant or irrelevant information) of attention. Models examining the effects of anxiety on sport performance have historically been separated into execution focus models and distraction theories. Execution focus models, such as the explicit monitoring hypothesis (Beilock & Carr, 2001) and the conscious processing hypothesis (Masters, 1992), suggest that anxiety causes attention to be directed towards the conscious control over the execution, or step-by-step execution, of the motor skill. In contrast, distraction models (e.g., ACT) suggest that anxiety, particularly worries, are cognitive resource intensive, leaving insufficient mental processes available to maintain attention towards task-relevant information, used for the optimal execution of the motor skill (Wilson, 2008). In line with the discussion of an integrative perspective of execution focus and distraction focus models by Nieuwenhuys and Oudejans (2012), within this thesis the perspective is adopted that anxiety affects perceptual-motor skill performance through distraction, where attention is directed away from task-relevant information. Adopting this perspective of a redirection of attention towards threat-related, task-irrelevant, information and/or towards a focus on the execution of the skill, stipulates that execution focus models can be categorised under the distraction theories. It is this direction of attention away from task-relevant information under anxiety conditions which is suggested to affect perceptual-motor skill performance, a feature of both distraction and execution focus models.

1.4 Anxiety and visual attention

1.4.1 Anxiety and visual attention: processing efficiency theory

Processing efficiency theory (PET) (Eysenck & Calvo, 1992) was developed to explain the relationship between cognitive performance and anxiety. PET intended to provide an explanation on how anxiety would affect performance in cognitive tasks whilst acknowledging scope to be applied to motor tasks. The original development of PET was based on work in the 1970s and 1980s related to the cognitive interference theory (CIT, Sarason, 1988). Although acknowledging the effects of worry on working memory capacity, Eysenck and Calvo (1992) highlight that worry about performance does not often result in impaired performance in cognitive and fine motor tasks (Eysenck & Calvo, 1992). Within a series of predictions, supported by empirical evidence, Eysenck and Calvo (1992) argue that worries, in the form of cognitive anxiety, pre-empts resources of working memory (e.g., the articulate loop and central executive). Therefore, a reduction in capacity to make use of these resources is available, which could impair sport performance. The second prediction suggests that cognitive anxiety, in the form of worries, serves as a motivational factor to increase effort on mobilizing resources of the working memory or use compensatory strategies to maintain performance. The use of additional processing resources led to the separation of processing efficiency from task effectiveness; task performance can be maintained (effectiveness) with the use of additional cognitive resources (i.e., effort) and hence reducing processing efficiency (Eysenck & Calvo, 1992). Although postulated, the functional and pathological foundations of processing efficiency were challenging to identify, due to the derivation of processing efficiency from both effectiveness and effort; two distinct mathematical operators. Hence both within the cognitive psychology and sport psychology domain, various alternative measures of processing efficiency are proposed such as secondary task performance, time to complete the task and visual search behaviour (Wilson, 2008). A major limitation in the development of PET, and its successor ACT, was its overreliance on studies comparing high trait anxious to low trait anxious individuals. Although Eysenck and Calvo (1992) state that the high trait anxious participants are likely to experience high state anxiety, based on the interaction between situational factors and the development of anxiety (Lazarus, Deese, & Osler, 1952), it was predominantly in the sport domain where the effects of state anxiety, in contrast to trait anxiety, on performance effectiveness and processing efficiency were examined. In 1997, 5 years after the publication of PET, PET featured in a discussion about the possible facilitative (Hardy, 1997) and debilitative effects (Burton & Naylor, 1997) of cognitive anxiety on sport performance, without being empirically tested in the sport domain. Williams and Elliott (1999) were one of the first authors to examine the application of PET in the sport setting. Visual search behaviour, as a measure of processing efficiency and visual attention, was examined under a high anxiety and low anxiety condition, in participants who observed a video based karate attack. Williams and Elliott (1999) identified a decrease in efficiency of visual search behaviour, evidenced by an increase in the number of fixations, fixation locations and reduced time attending to key locations of the display, in the high anxiety compared to low anxiety condition. Concurrently, performance (e.g., successful or unsuccessful blocking of attacks) improved under high anxiety conditions. These findings were explained through PET, in that performance effectiveness was maintained and improved, whilst performance efficiency (number of fixation locations per second (e.g., scan rate)) decreased due to attentional narrowing and reduced use of peripheral vision (Easterbrook, 1959) and/or hyper-vigilance (e.g., detecting non-relevant stimuli in the environment, PET). Although the results of Williams and Elliott (1999) provided support for PET, it is important to acknowledge that the video simulation, in contrast to an *in situ* condition, can result in an adaptation of visual search behaviour that does not reflect visual search behaviour in naturalistic environments (Dicks, Button, & Davids, 2010). In consecutive studies, support for the relevance of PET to examine the anxiety- sport performance relationship was provided by relating performance effectiveness (e.g., task execution measures or processes) and processing efficiency (e.g., visual search behaviour) under high and low anxiety conditions in tasks such as table tennis (Williams, Vickers, & Rodrigues, 2001), climbing (Nieuwenhuys, Pijpers, Oudejans, & Bakker, 2008) and rally car driving (Murray & Janelle, 2003; Wilson, Smith, Chattington, Ford, & Marple-Horvat, 2006) highlighting that anxiety affects visual search behaviour by means of changes in the direction of visual attention as well as differences in the pattern of visual search behaviour (Janelle, 2002).

1.4.2 Anxiety and visual search behaviour

The aforementioned studies examining the relevance of PET in the sport setting used visual search behaviour as measure of visual attention and processing efficiency to explain changes in sport performance under anxiety conditions. The effects of anxiety on visual search behaviour are reflected in changes in the length and frequency that gaze is directed towards task-relevant and irrelevant information as well as at a more general level in the number of fixation locations per second (i.e., scan rate). In addition, type of tasks (interceptive, reactive or closed-skill aiming tasks) and the inclusion of specific research paradigms (e.g., dual task) are expected to influence visual search behaviour (Janelle, 2002). For example, Wilson et al. (2006) identified that increased state anxiety did not affect scan rate (e.g., number of fixation locations per second) in a rally driving task, whereas participants with high trait anxiety did have a significantly higher scan rate compared to participants low in trait anxiety. In contrast, Murray and Janelle (2003), identified that scan rate significantly increased under high pressure conditions, where trait anxiety did not explain these differences in scan rate. These different findings can be explained through the used experimental set-up. The study by Murray and Janelle (2003) included a dual task paradigm, where participants had to identify and respond to peripheral cues. In contrast, the simulated rally driving task used in the study by Wilson et al. (2006) did not include this dual task element. This increase in task demands (e.g., the dual task) with more information to attend to, would explain these different findings in scan rate under high pressure conditions. This finding of an increase in scan rate under high anxiety conditions in reactive tasks reflects findings in interceptive tasks such as table tennis (Williams et al., 2001), where significant increases in scan rate were identified under high anxiety conditions with additional cognitive demands and the previously discussed study by Williams and Elliott (1999) in defending a karate attack. The aforementioned interceptive (e.g., table tennis, defending a karate attack) and reactive tasks (e.g., simulated rally driving) typically have a high number of task-relevant and irrelevant sources of information to visually explore, highlighting the relevance of scan rate as measure of visual search behaviour. In contrast, closed skill, self-paced aiming tasks typically have less contextual demands, temporal constraints and perceptual cues (Mann, Williams, Ward, & Janelle, 2007). Tasks, such as dart throwing, ten-pin bowling, archery and golf, typically have one or two targets to visually examine. Within these aiming tasks, in contrast to interceptive tasks, the relevant information from the environment needs to be acquired to plan and guide the intended movement a priori. Here, an increase in scan rate under anxiety conditions would indicate that the participant re-evaluates the position of key environmental stimuli. Indeed, within a golf putting task, Wilson, Smith and Holmes (2007) identified that the number of fixations on the target (e.g., hole) significantly increased under a high anxiety condition, compared to a low anxiety condition. Concurrently, a significant increase in time to complete the golf putt in the high anxiety condition was identified, suggesting that the increase in number of fixations at the target was related to the increase in trial length. Similarly, Wilson, Vine and Wood (2009) identified a significant increase in the number of fixations, of significant shorter duration, in a basketball free throw task, under high threat conditions, without significant changes in trial length. However, as identified by Wilson, Vine and Wood (2009), these changes were reflected in the direction of gaze to numerous areas of interest (AOIs) in close proximity to target area, and not in re-examining the location of the target AOI. These findings provide support for the concept that the effects of anxiety on visual search behaviour are reflected in a redistribution of visual attention from task-relevant to task-irrelevant information. Hence, changes in visual search behaviour under anxiety in aiming tasks can be described in changes to length of time gaze is directed to target and non-target locations. Within aiming tasks, studies specifically examine this via the length of the final gaze towards the target during the preparation and/or execution phase of the motor skill, the quiet eye (QE) (Vickers, 2007). In general, anxiety reduces the length of the QE in aiming tasks (Behan & Wilson, 2008; Causer, Holmes, Smith, & Williams, 2011; Nibbeling, Oudejans, & Daanen, 2012; Wilson et al., 2009). Although these studies identify that anxiety reduces the length of QE period it is often unclear to what extent this is reflected in the direction of visual attention towards other information in the environment, specifically due to the moderating effects of changes in trial length. For example, within a dart throwing task, Nibbeling et al. (2012) identified that under high, compared to low anxiety conditions, novice participants reduced the time looking at the target (e.g., bulls eye) by 50%, suggesting an increase in visual attention away from the target location during the aiming tasks. However, whilst the time to complete the trial increased (e.g., throwing 6 darts), there was no strong indication that other AOIs were attended more in the high anxiety conditions. Similarly, within an archery task, Behan and Wilson (2008) identified a significant reduction in the length of the QE under high anxiety conditions, albeit with a much smaller reduction in the QE length (11.5%) compared to Nibbeling et al. (2012), most likely due to the expression of the QE length as a percentage of trial length. In general, findings indicate that anxiety affects processing efficiency, as evidenced through changes in visual search behaviour. Specifically the observation of increases in scan rate, with more fixations of shorter duration, highlight a decrease in efficiency to extract information from the environment and therefore provides support for the relevance of PET. Similarly, the findings from the aforementioned studies provide support for the influence of state anxiety on broader attentional control where studies examined Attentional Control Theory (ACT, Eysenck et al., 2007), a theoretical update from PET. The development of ACT coincided with an enhanced understanding of the role of core executive functioning in attentional control and specifically the influence of distracting and threat-related stimuli in attentional control under anxiety conditions. Concurrently, ACT maintained the assumptions of the distinction between performance efficiency and effectiveness.

1.4.3 Attentional Control Theory

Central to the development of ACT is that task-irrelevant thoughts, in the form of worry, reduce the capacity of attention to be allocated towards processing of task-relevant information and thoughts, similar to the fundamentals of PET. However, ACT specifically stipulates the distinction between task-irrelevant thoughts (e.g., internal), from external task-irrelevant stimuli, presented in the environment, with comparable effects on processing efficiency. The role of visual attention in ACT is operationalised by the interplay between the goal-directed attentional system (top-down) and the stimulus-driven (bottom-up) attentional system (Corbetta & Shulman, 2002). ACT postulates that anxiety affects the balance of these attentional systems where the influence of goal-directed attentional control is reduced due to an increased role of the stimulus-driven attentional system (Bishop, 2008; Eysenck et al., 2007). ACT particularly suggests that anxious individuals have a reduced capacity to inhibit threatening stimuli (inhibition function of the central executive) and demonstrate longer response latencies disengaging from threatening stimuli (task-shifting function of the central executive) (Derakshan, Ansari, Hansard, Shoker, & Eysenck, 2009; Eysenck & Derakshan, 2011). For example, via examining response tendencies for identifying and disengaging from pictures with angry, neutral or happy facial expressions, Derakshan et al. (2009) identified that anxious individuals have a reduced capacity to inhibit threatening stimuli and longer response latencies when disengaging from threatening stimuli (i.e., it took longer to look away from the angry faces). Within more naturalistic and sport environments, in contrast to laboratory based cognitive tasks, studies have examined ACT to explain changes in visual attention under anxiety conditions and the role of goal-directed and stimulus-driven attention with mixed results (Causer et al., 2011; Nieuwenhuys, Savelsbergh, & Oudejans, 2012; Wilson et al., 2009; Wilson, Wood, & Vine, 2009; Wood & Wilson, 2010). Studies typically use self-paced aiming tasks (penalty kicks in soccer, golf putting and shooting tasks) where movement execution processes and visual attention can be assessed. For example, Causer et al. (2011) tested the predictions of ACT in a shooting task, through examining the effects of anxiety on changes in visual attention with a specific focus on QE length, an indicator of the goal-directed attentional system. Although the results identified a shorter duration of the QE with high state anxiety, the findings did not clarify whether anxiety affected overt visual attention to task-irrelevant or threating information and the stimulus-driven attentional system. Nieuwenhuys et al., (2012), examined shooting behaviour of police officers under high and low anxiety conditions. Visual search behaviour, shot accuracy and reaction time were examined in a shoot or not shoot scenario based on armed and unarmed suspects. Within this set-up, ACT would predict that police officers detect suspects earlier, irrespective of being armed or unarmed (e.g., a suspect is inherently a threat to the police officer). Indeed, the findings indicated that participants responded faster to either stimuli (i.e., armed or unarmed suspects) and decided to shoot more often under high anxiety conditions, irrespective of whether the suspect formed a real threat (i.e., armed or unarmed). More importantly, visual search behaviour was not affected by the anxiety manipulation (i.e., scan rate and fixation time were similar in low and high anxiety conditions) despite responding quicker to the suspects. The identified changes in performance behaviour, without changes in visual search behaviour, highlights that anxiety affected attentional cognitive processes without resulting in changes in overt visual attention to task-relevant visual information. These findings suggest that anxiety can affect the inhibition function at different levels of attentional control (e.g., pre-potent response inhibition, Friedman & Miyake, 2004), see section 1.5. Within a sport related setting, Wilson et al. (2009) examined the influence of anxiety on the stimulus-driven attentional system to examine the predictions of ACT. Soccer players, executing a penalty kick, visually attended longer towards the goal keeper (defined as a threat related stimulus) in a high pressure condition, compared to a low pressure condition. When the saliency of the goal keeper was changed (i.e., the goal keeper was allowed to wave his arms), further increases in visual attention to the goal keeper were identified (Wood & Wilson, 2010). These results provide support for ACT in that both anxiety, and changing the saliency of the goal keeper, influenced the stimulus-driven attentional system in that participants looked for longer at the goal keeper. There are two limitations to the aforementioned studies examining ACT in perceptual-motor skills. The identified significant changes in visual attention are often, but not always (e.g., Behan & Wilson, 2008), presented as an absolute measure of time, instead of, relative to trial time. Under high anxiety conditions, trial length typically changes in comparison to low anxiety conditions (Causer et al., 2011). Therefore, changes in trial length effect the composition and distribution of visual search behaviour and overt visual attention to al AOIs attended to. Specifically by selecting a single AOI as an absolute measure of visual attention (e.g., QE), it is challenging to infer whether the relative contribution, or ratio between attending to task-relevant and irrelevant information, is affected by anxiety or changes in trial length. For example, Causer et al. (2011), identified a reduction in absolute QE length under high anxiety conditions concurrently to a reduction in trial length. An expression of visual search behaviour relative to trial length could highlight whether the experimental condition influenced the distribution of visual attention in all AOIs, irrespective of changes in trial length.

A second limitation to the current studies on ACT in sport is that the distracting or threat related stimuli (e.g., goal keeper or armed suspect) played an important role in the successful execution of the task, or, demand response tendencies (e.g., ignore or engage with the stimuli) related to the identification and reaction to the stimulus. In real sport competitions athletes perform in dynamic environments with both task-relevant and information that is not directly relevant for the execution of the task (e.g., the crowd, other athletes or task irrelevant objects). Specifically the use of these task-irrelevant stimuli can assess the effects of anxiety on the inhibition function and clarify the role of the stimulus-driven attentional system. This is investigated in chapter 5 of this thesis where participants completed golf putts under low and high anxiety conditions to examine whether task-irrelevant stimuli were attended to more under anxiety or whether anxiety results solely in changes in attending to task-relevant stimuli.

1.5 Inhibition and visual attention

Stimuli that are inherently irrelevant to task completion allow for the examination of the influence of anxiety on the inhibition function and the different types and functions of inhibition. A taxonomy of inhibition processes can be classified according to an intentional dimension (classified as irrelevant after awareness) and unintentional (prior to awareness), at a behavioural (motor responses) and cognitive level (mental processes related to unwanted and irrelevant thoughts). This classification of inhibition dimensions relates directly to information processing models where inhibition is exhibited at perceptual level, working memory level and level of decision making of effector processes. However, the categorisation of these inhibition dimensions is conceptual and lacking empirical support (Friedman & Miyake, 2004). To this extent Friedman and Miyake (2004) separated the inhibition functions into pre-potent response inhibition, resistance to distractor interference and resistance to proactive interference. Pre-potent response inhibition relates to the ability to actively suppress habitual responses, where resistance to distractor interferences is the ability to resist interference from task-irrelevant information in the external environment. Resistance to proactive interference relates to the ability to resist the influence of information in the working memory of previously task-relevant information, but now irrelevant information. Performance on tasks that assess the different inhibition functions were examined, to identify whether these different inhibition functions can be functionally separated (Friedman & Miyake, 2004). The findings indicated that both pre-potent response inhibition and resistance to distractor interference were closely related, however, both were distinct from resistance to proactive interference. The finding that pre-potent response inhibition and resistance to distractor interference are closely related, supports the relevance of ACT in examining the effects of anxiety on perceptual-motor performance in aiming tasks. For example, reduced pre-potent response inhibition can explain why a golfer starts to look at club head movement during the putting stroke instead of the ball, whereas looking away from the hole towards task-irrelevant information (e.g., the crowd, irrelevant objects) relates to resistance to distractor interference. This highlights that previous studies examining the relevance of ACT in naturalistic environments predominantly assess pre-potent response inhibition (e.g., the goal keeper, armed suspects) whilst not examining the role of resistance to distractor interference.

1.5.1 Measures of inhibition

Assessing changes in inhibition under anxiety conditions can come from both behavioural measures, such as reaction time, or from visual search behaviour analysis. Behavioural measures can identify response time in reacting to task-relevant and irrelevant stimuli. For example, evidence from a cognitive task such as an emotional Stroop test, identifies that high anxious participants react more slowly in identifying task-relevant features (the colour of the presented word) with threat related connotations (i.e., when the presented word is threat related) (Derakshan & Eysenck, 2009). However, this does not identify which part of the inhibition function would be affected by anxiety. A clearer examination of the role of anxiety on the inhibition function with external task-irrelevant stimuli can come from visual search behaviour analysis to accompany the behavioural indices (Clarke, MacLeod, & Guastella, 2013; Eysenck & Derakshan, 2011). A reduction in inhibition of task-irrelevant stimuli under anxiety would result in more eye movements directed towards the task-irrelevant stimuli and longer response latencies to move away from these, as evidenced by results using the anti-saccade test (Derakshan et al., 2009). However, within the anti-saccade task, participants are instructed to look away, towards a target stimuli, when a non-target stimuli is presented, making the non-target stimuli task-relevant and hence testing the pre-potent response inhibition and not resistance to distractor interference inhibition (Friedman & Miyake, 2004). Tasks that more purely assess distractor interference typically present a task-relevant stimulus in the presence of task-irrelevant stimuli of different saliency or emotional valence. For example the singleton search task asks participants to search and identify a stimuli (goal-directed attentional control) in the presence of distractor stimuli (stimulus-driven attentional control). Here, response time to identify target stimuli is a measure of goal-directed attention and visual attention towards the distracting stimuli a measure of stimulus-driven attention. Within these paradigms, the effects of anxiety on the inhibition function are less pronounced than tasks that measuring pre-potent response inhibition (Moran & Moser, 2015). Studies using emotional facial distractors (e.g., happy and angry faces) surrounding a target stimuli identified no evidence for distractor interference in overt visual attention, however, response time to identify target stimuli was slower (Derakshan & Koster, 2010). More importantly, within a study on the effects of salient neutral stimuli, unrelated to task performance, it was identified that trait anxiety affected visual attention to these stimuli, where the effect of attending to these stimuli disappeared within a comparison between high and low state anxious participants (Moran & Moser, 2015). In conclusion, the effects of anxiety on inhibition are evidenced by changes in behavioural measures (e.g., longer response times) but are not always reflected in changes in visual search behaviour (Nieuwenhuys et al., 2012) where these effects are more pronounced in tasks with active engagement with non-target stimuli (e.g., pre-potent inhibition and anti-saccade task) compared to tasks examining resistance to distractor interference.

1.6 Anxiety and performance

Central to both PET and ACT is that performance effectiveness can be maintained in high pressure conditions at the expense of increasing processing resources to concurrently process task-relevant and irrelevant information. Performance can be described in outcome measures (e.g., win/loss, goals scored or balls holed), measures of the accuracy in achieving the outcome (distance from the target), variability in the outcome over multiple attempts, as well as process measures of movement patterns. Where performance outcome provides the ultimate measure of whether an athlete is successful or unsuccessful, it has the limitation of being influenced by external factors outside the control of the athlete and has low sensitivity to reflect small changes in performance that are expected due to anxiety. Indeed, the results of several meta-analyses, including various outcome measures of performance, identified that anxiety has small effects on performance outcome (Craft et al., 2003; Woodman & Hardy, 2003). The performance measures highlighted above can be ordered in their sensitivity to describe performance. Changes in movement patterns during the execution of motor skills are likely to influence the accuracy of the performance, where changes in accuracy are expected to influence the outcome. This highlights that in the examination of the effects of anxiety on sport performance, several measures of performance need to be examined. Due to the self-paced nature, particularly aiming tasks allow for the examination of these process measures of performance (e.g., movement execution) concurrently to measures of accuracy, variability and outcome. For example, within a shooting task, Causer et al. (2011) identified that participants had a reduction in success rate under high anxiety, concomitant to larger lateral gun displacement and variability. Similarly, within a golf putting task, Cooke et al. (2010) identified that anxiety did not affect performance outcome, however, participants putted more accurately under high anxiety conditions, concurrent to a reduction in variability in movement patterns. These findings support the notion that changes in movement patterns can affect performance accuracy but do not automatically translate into changes in the outcome. Although kinematic variables describe the movement pattern, it is important to ensure that the variables recorded accurately relate to performance outcome and accuracy measures.

Variation in movement patterns within the execution of motor skills do not automatically translate in changes in the outcome of the movement pattern (e.g., ball release speed) reflecting that variability in movement patterns emerge to accommodate for changes in task-constraints and consistency in the outcome of the movement pattern (Seifert, Button, & Davids, 2013). For example, a golf player might adjust his or her velocity profile during the downswing to adjust for variation in the length of the backswing to ensure that a similar impact velocity is achieved as in putts with alike constraints. This suggests that within aiming tasks, and golf putting specifically, performance indicators that influence ball velocity and direction need to be used. Within golf putting, club head orientation at ball impact is the main performance indicator of ball direction (Karlsen, Smith, & Nilsson, 2008). Ball speed is reflected in impact velocity of the club head, where impact velocity of the club head is determined by the length of the backswing (Delay, Nougier, Orliaguet, & Coello, 1997). Hence, the key kinematic performance indicators that influence golf putting accuracy most are backswing length and club head impact velocity and angle. This explains that studies identifying significant changes in movement time or acceleration of the golf putter under high anxiety conditions, without assessing the key performance indicators of the golf putt, are unable to conclude that these kinematic variables affect performance accuracy (Tanaka & Sekiya, 2010).

1.7 The endocrine response

Concurrently to the development of negative emotions and challenge and threat states in high-pressure situations, these states and emotions concurrently trigger a biological stress response through activation of the SNS and HPA-axis (Dienstbier, 1989). Several biomarkers indicate activation of both these pathways. The salivary enzyme α-amylase (sAA), an indicator of norepinephrine (NE) release, can be used as a measure of SNS activation (Granger, Kivlighan, El-Sheikh, Gordis, & Stroud, 2007; Rohleder, Nater, Wolf, Ehlert, & Kirschbaum, 2004). Where salivary cortisol concentration has been extensively used as indicator of HPA-axis activation (Alix-Sy, Le Scanff, & Filaire, 2008; Hellhammer, Wüst, & Kudielka, 2009;

Lovallo & Thomas, 2000; Salvador, 2005) (see chapter 3 for further details of the assessment of SNS and HPA-axis activation). However, HPA axis and SNS reactivity is distinct in both the psychological determinants that trigger activation of both pathways as well as the temporal pattern of identifying activation through biomarkers. Activation of the HPA-axis is typically linked to both physiological stress (e.g., inflammatory stress, chronic excessive exercise), psychosocial stressors and negative emotions related to lack of control, possible failure, threat and an unpredictable outcome, whereas SNS activity is more associated with high behavioural efforts and challenged states without distress (Dickerson & Kemeny, 2004; Hellhammer et al., 2009; Henry, 1992). In addition, activation of the SNS is quicker, where changes and peak levels of NE and sAA are typically reported within minutes following exposure to stress (Nater & Rohleder, 2009). In contrast, salivary cortisol typically peaks at 20 minutes following exposure to stress (Dickerson & Kemeny, 2004). Hence, it is expected that differences in the athlete's appraisal of the stress of a competitive sport environment relates to distinct SNS and HPA-axis reactivity; the more negative and threatening evaluation relating to HPA-axis and SNS activation and the more challenging to SNS activation (Dienstbier, 1989). Where SNS and HPA-axis activation to challenge and threat states forms the basis of the BPSM, the BPSM proposes cardiovascular measures to identify responsiveness of these systems. As such, SNS activation is reflected in an increased heart rate and cardiac output and reduction in total peripheral resistance (i.e., vasodilation). In contrast, a threat state is associated with a similar increase in heart rate, but with an increase or stabilization in total peripheral resistance (i.e., vasoconstriction) and no changes in cardiac output. The cardiovascular measures of challenge and threat states tend to show stronger correlations with HPA-axis activation then SNS activation (Cacioppo et al., 1995). Although SNS and HPA-axis activation are linked to experienced emotions, it is of interest that studies typically identify weak correlations between self-reported emotional responses and neuroendocrine responses (Engert et al., 2013) and self-reported measures of challenge and threat demands and cardiovascular markers (Vine, Moore and Wilson, 2016). This highlights the important distinction between the perceived experience of emotions such as anxiety and physiological indices of stress associated with the neuroendocrine response (see chapter 4 for further details).

1.7.1 The anticipatory and reactive endocrine response

Within the psychology domain, activation of the HPA-axis and SNS is associated with experiencing psychosocial stressors. Depending on the experimental set-up this can lead to an anticipatory stress response and/or reactive stress response. Studies in the psychology domain typically expose participants to a psychosocial stress task where full disclosure of the stressor is not provided a priori. For example, Dickerson and Kemeny (2004) identified in their meta-analysis of the cortisol response to acute psychological stressors that cortisol is released under motivated, goal-relevant performance tasks during social-evaluative conditions *following* exposure to these stressors but not in anticipation to. In contrast, within the sport environment, an appraisal and evaluation of the demands of competition are typically completed a priori, leading to an emotional reaction (e.g., an increase in cognitive and somatic anxiety) in anticipation to the competition (Craft et al., 2003). Such an anticipatory stress response is also identified in participation in extreme sports (Hare, Wetherell, & Smith, 2013; Meyer et al., 2015) as well in some social evaluative laboratory stressors (Dickerson & Kemeny, 2004). An anticipatory increase in cortisol before sport competition is important for the athlete to prepare for both the psychological and physiological demands of the competition (e.g., heightened arousal, glucose release), suggesting a positive effect of cortisol on high intensity exercise. In fine motor skills, elevated cortisol is suggested to negatively affect sport performance through activation of cerebral cortical activity, leading to disruption in the refinement of motor control (Hatfield et al., 2013), in addition to its influence on executive functioning and processing of visual information (Shields, Bonner, & Moons, 2015). However, stress reactivity, in particular HPA-axis activation, shows large inter-individual variation, which could explain variation between athletes in disruption to perceptual-motor skills performance under pressure.

1.7.2 Factors influencing the endocrine response

HPA-axis and, to a lesser extent, SNS activation show large inter-individual variability that is influenced by factors such as genetic predisposition and determinants such as gender, age and habituation (Boyce & Ellis, 2005; Kudielka et al., 2009). Kirschbaum, Wüst and Hellhammer (1992) identified differences in HPA-axis reactivity between genders; males demonstrated increased levels of salivary cortisol concentration in anticipation of participating in a social stress task, but this anticipatory stress response was absent in females. In contrast, Van Stegeren, Wolf and Kindt (2008) did not identify gender differences in the cortisol response to a social stress task. It is relevant to note that the gender differences in HPA-axis activity in response to social stressors are still unclear due to confounding effects of factors such as age, contraceptive use and predominantly due to differences in the appraisal of psychosocial stressors used in stress protocols (Kudielka & Kirschbaum, 2005). Gender differences in HPA-axis activity have also been the primary aim of studies in the sport domain. Kivlighan, Granger and Booth (2005) identified no gender differences in cortisol concentration in the anticipation phase of competition, where Salvador (2005) concluded that the anticipatory cortisol response to sport competition is often absent in women. Therefore, it would be of interest to investigate whether HPA-axis activity in anticipation to sport competition is different between males and females. This can inform laboratory based studies to consider using males, females or a mixed gender study population, if differences in HPA-axis activity are evident in real sport competition.

Where the effects of gender differences on HPA-activation is inconclusive, an even more complex interaction takes place with the effects of age, experience and habituation to stressful events. Experienced athletes have had more exposure to stressful competition. It is suggested that repeated exposure to stressful events reduces the HPA-axis activation in social stress tasks (Wüst, Federenko, van Rossum, Koper, & Hellhammer, 2005) as well as in extreme sports (e.g., sky-diving) (Deinzer, Kirschbaum, Gresele, & Hellhammer, 1997). Although the peak cortisol concentration before sky-diving is not different between experienced versus less experienced sky-divers (Hare et al., 2013), the pattern of cortisol reactivity is distinct. More experienced sky-divers have a quick rise and reduction in contrast to earlier increases and a prolonged period of increased cortisol in less experienced sky-divers (Meyer et al., 2015). Therefore, it is anticipated that age and experience might play a greater role in the pattern of cortisol reactivity than in the magnitude of the cortisol response.

1.7.3 The endocrine response in real sport competition

The endocrine response around real sport competition has received considerable interest in the literature, where the effects of exercise induced changes and/or situational factors to the cortisol response are regularly examined (Casto & Edwards, 2016; L. D. Hayes, Grace, Baker, & Sculthorpe, 2015; Salvador, 2005). Studies particularly examine changes in cortisol from before competition to after competition in relation to performance (Gonzalez-Bono, Salvador, Serrano, & Ricarte, 1999), game location (Carré, Muir, Belanger, & Putnam, 2006) or gender (Thatcher, Thatcher, & Dorling, 2004). Cortisol tends to increase following sport competition in comparison to before competition, irrespective on competition outcome, game location or gender (Casto & Edwards, 2016). Particular studies that rely on high intensity exercise for longer duration report higher changes in cortisol, compared to low intensity exercise activities for shorter durations, irrespective of experiencing psychosocial stressors (L. D. Hayes et al., 2015; Salvador, 2005). Hence, one of the key challenges in investigating the psychosocial effects of sport competition on the cortisol response is separating cortisol secretion due to emotional stress from the physiological demands of the exercise. Exercise intensity influences blood glucose levels and declining blood glucose levels elicit the hypothalamus to secrete the corticotrophin releasing hormone (CRH). CRH triggers the release of the adrenocorticotropic hormone (ACTH) which activates the adrenal cortex to release cortisol (Brooks, Fahey, & White, 1996). The release of cortisol in this mechanism supports homeostasis of blood glucose levels by stimulating gluconeogenesis from amino acids and mobilizing free fatty acids (FFA) from adipose tissue (Brooks et al., 1996). Cortisol secretion with the aim of mobilizing energy sources is therefore independent from experiencing psychosocial stressors and is mainly a function of exercise intensity. Indeed, Jacks et al. (2002) identified that blood glucose significantly decreased whilst salivary cortisol significantly increased after 59 minutes of high intensity exercise at 62% and 76% of $\dot{V}O_2$peak in comparison to rest and lower intensity exercise. This finding is supported by the conclusion from Kudielka et al. (2009) that both maximal physical exercise and sustained exercise above 70% of the $\dot{V}O_2$max will significantly increase cortisol concentrations compared to more moderate exercise intensities. This highlights that to examine the influence of psychosocial stress on the cortisol response around sport competition studies should either refrain from sports with high-intensity components or examine the anticipatory stress response. Where studies regularly report pre-competition levels of cortisol (Filaire, Maso, Sagnol, Ferrand, & Lac, 2001) and reviews highlight the presence of an anticipatory rise in cortisol before sport competition (Hayes et al., 2015), there has not been a systematic analysis of the magnitude of this anticipatory cortisol response and moderating variables of this response. A meta-analysis of the anticipatory cortisol response before competition could provide this evidence.

1.7.4 The endocrine response in laboratory based stress manipulations

The effects of anxiety on sport performance when examined through performance, analysis of movement and visual attention are typically conducted in laboratory environments where a simulation of a social evaluative and competitive sport environment is created. The advantage of utilising a laboratory compared to outdoor or 'live' sporting situation is the level of control afforded to the study at the expense of losing ecological validity of the naturalistic setting. Particularly cortisol, as an indicator of HPA-axis activity, is commonly assessed in the general psychology domain as an indicator of stress (Hellhammer et al., 2009). Based on the systematic analysis of laboratory studies of acute psychological stressors, Dickerson and Kemeny (2004) identified that cortisol is released under motivated, goal-relevant performance tasks during social-evaluative conditions. These psychosocial factors resemble the psychological stressors of competitive sport, and relate to the psychosocial stressors used to induce stress in the sport psychology domain. Within the sport psychology domain, studies adopt Baumeister and Showers' (1986) suggested methodological approaches including a combination of self-presentation and motivational stimuli such as financial incentives (Cooke et al., 2010; Hardy, Mullen, & Jones, 1996; Wilson et al., 2009), performance evaluation (Cooke et al., 2010; Hardy et al., 1996; Wilson et al., 2009) and/or an audience (Hasegawa, Koyama, & Inomata, 2013; Mesagno, Harvey, & Janelle, 2011) to recreate a competitive environment. With single or a combination of these manipulations, studies successfully increase the levels of cognitive and somatic anxiety in comparison to “do your best” or control conditions (Cooke et al., 2010; Hardy et al., 1996; Wilson et al., 2009). However, the reported increases in anxiety are typically below that reported around real sport competition. Specifically when studies use the CSAI-2, a comparison to normative values, derived from real sport competition, tend to show that participants in laboratory based stress manipulation experience moderate levels of anxiety, below that observed in real competition (Chamberlain & Hale, 2007; Mullen & Hardy, 2000). Where anxiety is commonly measured to indicate whether a stress manipulation is effective, there are currently limited studies that have evaluated the endocrine response in a competitive laboratory sport setting. Lautenbach et al. (2014) aimed to investigate the relationship between cortisol reactivity and tennis serve performance, however, cortisol was not significantly elevated by the mental arithmetic manipulation. Mullen et al. (2016) identified a significant increase in sAA from baseline in simulated rally driving competition with financial incentives and cooperative competition. Though, cortisol was not assessed. Although alternative indicators of SNS-activity, such as heart rate variability and galvanic skin response, are regularly used in the sport psychology domain, it is surprising that more direct biomarkers (e.g., cortisol, sAA or NE) are limitedly used. Specifically as these biomarkers are suggested to have a direct effect on cognitive functioning and show weak associations with self-reported measures of anxiety. As there is currently limited evidence to what extent laboratory based stress manipulation in the sport psychology domain affect the endocrine response, there is the need to evaluate whether the SNS and HPA-axis can be successfully activated in a competitive laboratory sport setting using psychosocial stressors. In addition, these results can be compared to evidence from a meta-analysis of the anticipatory cortisol response in real sport competition to identify whether the laboratory based stress manipulation creates an endocrine response comparable to real sport competitions.

1.8 The endocrine response and cognitive functioning

An anticipatory increase in cortisol before sport competition is important to prepare for the psychological and physiological demands and is suggested to affect sport performance through its influence on cognitive processes. Cortisol, released from the adrenal gland following activation of the HPA-axis, is able to pass the blood-brain barrier and receptors for glucocorticoids are extensively present in brain regions associated with core executive functioning. Within this context it is of interest that acute stress and activation of both the SNS and the HPA-axis are affecting pre-frontal-cortex (PFC) activity and working memory (WM) functioning. Independently from HPA-axis activity, norepinephrine, an indicator of SNS activity, demonstrates an inverted U-relationship with WM functioning, where below and above "optimal" NE concentrations, negatively affects WM processing (Arnsten & Li, 2005). In addition, there is evidence that a negative influence of cortisol on WM only appear with a combined influence of NE (Qin, Hermans, van-Marle, Luo, & Fernández, 2009). Hence, there is the suggestion that stress reactivity (e.g., changes in NE and cortisol) influences brain regions related to cognitive processing. To further explore this, studies have particularly examined the influence of cortisol on core executive functioning via administering exogenous cortisol, blocking glucocorticoid receptors or using stress manipulation to increase cortisol. Studies suggest that cortisol affects working memory both positively (Stauble, Thompson, & Morgan, 2013) and negatively (Oei, Everaerd, Elzinga, Well, & Bermond, 2006). Of interest is the examination of the role of cortisol in the inhibition of task irrelevant information (e.g., resistance to distractor interference), as proposed by ACT. Schwabe et al. (2013) identified, through mineralocorticoid receptors blockage (e.g., PFC receptors linked to situational appraisal and involved in coordination multiple cognitive processes), that stress induced changes in cortisol correlated to enhancement of inhibitory control. Specifically, individuals with increased cortisol responded quicker and were more accurate in a stop-signal task, a task that measures pre-potent response inhibition and is associated with activation of the ventrolateral prefrontal cortex (VLPFC). In contrast, Skosnik, Chatterton, Swisher and Park (2000) identified negative effects of cortisol, and sAA, on the inhibition function in a negative priming task. However, the negative priming task is a measure of the central executive shifting function, where the stop-signal task used by Schwabe et al. (2013) assesses the inhibition of a pre-potent motor response (e.g., in the majority of trials a motor response is needed). Together these findings indicate that cortisol affects executive functioning; cortisol has a negative effect on the shifting function whereas cortisol has a positive effect on pre-potent response inhibition. These findings are support by a meta-analysis on the effects of exogenous cortisol administration on core executive functioning (Shields et al., 2015). Shields et al. (2015) identified that cortisol enhanced pre-potent response inhibition and inhibition of distractor interference in the period from 15-135 minutes post administration. In contrast, the shifting function was not influenced by cortisol administration whereas exogenous cortisol had a negative effect on working memory. Therefore, these findings suggest that moderate levels of cortisol are functionally associated with reduced reaction time in identifying task-relevant stimuli, increased inhibition of aversive stimuli and inhibition of pre-potent motor responses, in comparison to low and high levels of cortisol secretion. These effects of cortisol are due to the activation of the VLPFC by cortisol, where increased activity in the VLPFC is associated with enhanced pre-potent motor response inhibition and orienting to task-relevant stimuli (Levy & Wagner, 2011). This enhancement in inhibition of aversive and task-irrelevant stimuli with moderate levels of cortisol can be related to sport performance and indicate that cortisol could facilitate sport performance (Taylor, Ellenbogen, Washburn, & Joober, 2011). In contrast, high levels of cortisol are associated with a reduction in inhibition of task-irrelevant stimuli, suggesting a debilitative effect on sport competition (Shields et al., 2015). Thus, moderate levels of cortisol might positively influence performance compared to low and high levels of cortisol, supporting the presence of an inverted U-relationship between cortisol and performance. Despite the evidence of a functional link between cortisol concentration and the inhibition of pre-potent motor responses and resistance of distractor interferences, limited studies have assessed this in more naturalistic scenarios. Akinola and Mendes (2012) identified that, following exposure to social stressors, police officers with larger cortisol increases made less mistakes in identifying potential threatening stimuli (images of suspects with or without a gun) in a shoot, no-shoot paradigm. Hence it would be of interest to explore the link between endocrine reactivity and visual attention in more naturalistic and specifically sport environments. In conclusion, ACT postulates that anxiety, in the form of worry, negatively affects attentional control towards information that is relevant for task performance. The efficiency of task performance is impaired via the influence of anxiety on the stimulus-driven attention system at the expense of the goal-directed attentional system. Although ACT specifies that anxiety effects several executive functions, the inhibition function (e.g., inhibiting pre-potent responses, resistance to distractor interference) are of particular interest to sport performance as these relate to the inhibition of both worries about performance (e.g., cognitive anxiety) as well as visually attending to task-irrelevant information (distractor interference), in contrast to attending to task-relevant thoughts and environmental stimuli. Whereas ACT specifically addresses the influence of cognitive anxiety on attentional control, there is abundant evidence that inhibition function is influenced by the endocrine response (see above). Although self-reported assessment of emotional responses (e.g., anxiety) is common in the sport domain, it is important to highlight that the emotional and endocrine stress response shows weak associations. A weak associations between emotional stress response and the SNS and HPA-axis stress pathways indicates the independence of both stress pathways (Engert et al., 2013; Nater et al., 2005; van Stegeren et al., 2008).

1.9 Endocrine response and performance execution

The examination of the influence of the endocrine response on sport performance predominantly focusses on the relationship between stress reactivity and the outcome of sports events. As highlighted earlier, both the influence of the intensity of the exercise combined with the use of outcome measures of performance, limited the explanatory evidence of a relationship between stress reactivity and performance. Within experimental controlled laboratory settings studies have attempted to examine the role of stress reactivity on performance execution and motor control. Particularly cortisol has been examined in this respect, as brain regions associated with the coordination of motor control (e.g., motor cortex, cerebellum) have high levels of glucocorticoid receptors. Increased HPA-axis activity, and the release of cortisol, would increase cortico-cortical input to the brain regions associated with planning and execution the movement. Evidence from electroencephalogram (EEG) analysis identified that the execution of an aiming task under high pressure conditions elevate cerebral cortical activity in regions associated with motor control over neutral conditions (Hatfield et al., 2013). Concurrently, the increase in cerebral activity under stress, accompanied by an increase in cortisol, resulted in a significant increase in the variation in movement patterns during the aiming action, but did not affect outcome or variability in outcome (Hatfield et al., 2013). Further support for a conceptual link between cortisol and motor skill execution, comes from the work on rodents by Metz, Jadavji and Smith (2005). The influence of cortisol on reaching behaviour was examined under both experimental induced stress and exogenous cortisol administration. The results identified that cortisol, independently of stress induced changes, negatively influenced the accuracy of reaching behaviour. Together, these findings highlight that increased levels of cortisol influence cortico-cortical dynamics, in that the fine control of motor movement is affected. Although changes in performance execution are expected, it is likely that these do not automatically translate into changes in performance outcome. This is evidenced by Lautenbach (2017) who observed an increase in cortisol following a stress manipulation dissociated from the performance task. However, performance on the golf putting task, expressed in number of putts holed, was not significantly affected by the increase in cortisol. These findings highlight that the effects of the endocrine response in performance might not be strong enough to affect performance outcome and warrant the use of performance execution variables, in contrast to performance outcome measures. In conclusion, there is theoretical evidence that explains how cortisol can affect performance execution in perceptual-motor skills. However, findings are affected by the outcome measures used to assess performance and/or stress manipulation that are unrelated to the performance task.

1.10 Challenge and Threat states and performance

The BPSM postulates that a challenged state facilitates performance whereas threat states negatively influences performance (Blascovich & Mendes, 2000). However, the initial evidence from the link between threat and challenge states and performance predominantly examined these in cognitive tasks. More recently (e.g., Moore et al., 2012) studies have examined the effects of these states on perceptual-motor performance, including the examination of underlying mechanisms (e.g., attentional control, interpretation of emotions) explaining changes in performance. For example, Moore et al. (2012) examined the effects of a challenge and threat manipulation on golf putting performance in novice participants. Cardiovascular indices of challenge and threat, emotional responses and process measures of performance (e.g., QE, muscular activity and putting kinematics) were assessed. The challenge and threat manipulation adopted by Moore et al. (2012) successfully created challenge and threat states, evidenced by significant changes in both cardiovascular indices of challenge and threat and self-reported demand evaluation. In addition, the challenge group outperformed the threat group whilst the challenge group had a significantly longer QE duration and demonstrated more fluent movement patterns (i.e., acceleration profiles) with reduced muscular activity in golf putting relevant muscles. More importantly, Moore et al. (2012) identified that the significant differences in putting accuracy between threat and challenged group could be explained by the significant changes in movement kinematics. Similar findings are identified in correlational design studies where the evaluation of sport competition as a challenge instead of a threat results in better performance in cricket batting (Turner et al., 2013), golf competition (Moore, Wilson, Vine, Coussens, & Freeman, 2013) and netball shooting (Turner, Jones, Sheffield, & Cross, 2012). The conclusion that a challenged state, in comparison to a threatened state, results in superior performance is supported by a recent systematic review of studies adopting cognitive and behavioural tasks (Hase et al., 2018). Although the cardiovascular indices of challenge and threat are commonly assessed, limited studies assess the endocrine response associated with challenge and threat states. This is of particular interest, as SNS activation (assessed via sAA) demonstrates more consistent reactivity within participants, where HPA-axis reactivity (i.e., cortisol) shows large inter-individual differences related to a more threatening appraisal of social evaluative situations and greater emotional responses in these situations (Balodis, Wynne-Edwards, & Olmstead, 2010; Gaab, Rohleder, Nater, & Ehlert, 2005; van den Bosch et al., 2009).

1.11 Aims of Thesis

In light of the current evidence of the role of anxiety and the endocrine response on performance, performance execution and visual attention the aims of this thesis are to

1) Systematically examine the relationship between the anticipation of participation in sport competition on the cortisol response and to identify the influence of moderator variables on this response.
2) Examine the endocrine response during the execution of a perceptual-motor skill in a pressure manipulation including commonly used self-presentation and motivational stimuli.
3) Examine differences in performance, performance execution and visual search behaviour in a golf putting task in a low and high pressure manipulation.
4) Examine whether variance in the endocrine response influences performance, performance execution and visual search behaviour in a golf putting task.

Chapter 2: The anticipatory stress response to sport competition; a systematic review with meta-analysis of cortisol reactivity

Note: The results of Chapter 2 are published as van Paridon, K. N., Timmis, M. A., Nevison, C. M., & Bristow, M. (2017). The anticipatory stress response to sport competition; a systematic review with meta-analysis of cortisol reactivity. *BMJ Open Sport & Exercise Medicine*, *3*(1), e000261 and were previously presented as Van Paridon, KN., Timmis, MA., Nevison, CM., & Bristow, M. (2016). The anticipatory stress response to sport competition; a meta-analysis of cortisol reactivity. Oral presentation, ECSS, 6-9 July, Vienna.

2.1 Introduction

Athletes are often required to perform complex sporting skills in challenging and social evaluative environments. The subjective evaluation and appraisal of the athlete's ability to cope with the stressors of competition influence the development of negative emotional states (Eysenck et al., 2007). These negative emotions (e.g., anxiety) are expected to trigger a biological stress response through activation of the sympathetic nervous system (SNS) and the hypothalamic-pituitary-adrenal (HPA) axis with the hormone cortisol as a marker of HPA-axis activation (Boyce & Ellis, 2005). However, both pathways are activated by distinctive psychological determinants (Henry, 1992). Challenge and effort are linked to SNS activation, whereas lack of control, harm and unpredictability outcome are more associated with HPA-axis activation (Dickerson & Kemeny, 2004; Hellhammer et al., 2009; Henry, 1992). Due to the high level of agreement between serum and salivary cortisol concentrations and the ease of collection, studies more regularly use salivary cortisol as an indicator of HPA-axis activation over serum analysis (Kirschbaum & Hellhammer, 1994). Based on the systematic analysis of laboratory studies of acute psychological stressors, Dickerson and Kemeny (2004) identified that cortisol is released under motivated, goal-relevant performance tasks during social-evaluative conditions. As these psychosocial factors resemble the psychological stressors of competitive sport, it is of interest to systematically examine whether participation in sport competition activates the HPA-axis. Craft et al. (2003) identified via a meta-analysis the presence of an emotional response (e.g., cognitive and somatic anxiety) to anticipating sport competition. In addition, Hayes et al. (2015) systematically examined the physiological effects of sport competition on the cortisol response and concluded that an increase in cortisol after sport competition was influenced by the timing of pre-competition sampling and in particular the suggested presence of an anticipatory stress response.

A strong anticipatory rise in cortisol has been identified in anticipating participation in extreme sports (Hare et al., 2013; Meyer et al., 2015) as well as in social evaluative laboratory stressors (Dickerson & Kemeny, 2004). An anticipatory increase in cortisol before sport competition is important to prepare for the psychological and physiological demands and is suggested to affect sport performance through its influence on cognitive processes (e.g., prefrontal cortex-amygdala activation and de-activation (Bishop, Duncan, Brett, & Lawrence, 2004; Dedovic, Duchesne, Andrews, Engert, & Pruessner, 2009). There is evidence that a moderate increase in cortisol is associated with reduced reaction time to identify task relevant stimuli and increased inhibition of aversive stimuli (e.g., pictures of fearful faces or violent scenes) in comparison to low and high levels of cortisol secretion, which could facilitate sport performance (Taylor et al., 2011). In contrast, high levels of cortisol are associated with a reduction in inhibition of task irrelevant stimuli, suggesting a debilitative effect on sport competition (Shields et al., 2015). Thus, moderate levels of cortisol might positively influence performance compared to low and high levels supporting the presence of an inverted U-relationship between cortisol and performance.

Variety in HPA-axis activation and cortisol reactivity is influenced by factors such as genetic predisposition as well as determinants such as gender, age and habituation (Boyce & Ellis, 2005; Kudielka et al., 2009). Kirschbaum, Wüst and Hellhammer (1992) identified that males demonstrated increased levels of salivary cortisol concentration in anticipation of participating in a social stress task, but this anticipatory stress response was absent in females. In contrast, Van Stegeren, Wolf and Kindt (2008) did not identify gender differences in cortisol response. It is relevant to note that the gender differences in HPA-axis activity to social stress tasks are still unclear due to confounding effects of factors such as age, contraceptive use and predominantly due to differences in the appraisal of psycho-social stressors used in stress protocols (Kudielka & Kirschbaum, 2005). Gender differences in HPA-axis activity have also been the primary aim of studies in the sport domain. Kivlighan, Granger and Booth (2005) identified no gender differences in cortisol concentration in the anticipation phase of competition. Salvador (2005) concluded that the anticipatory cortisol response to sport competition is often absent in women. Therefore, an investigation into HPA-axis activity in anticipation to sport competition should consider the moderation effects of gender.

Where the effects of gender differences on HPA-activation is inconclusive, an even more complex interaction takes place with the effects of age, experience and habituation to stressful events. Experienced athletes have had more exposure to stressful competition. It is suggested that repeated exposure to stressful events reduces the HPA-axis activation in social stress tasks (Wüst et al., 2005) as well as in extreme sports (e.g., sky-diving) (Deinzer et al., 1997). However, the peak cortisol concentration before sky-diving is not different between experienced versus less experienced sky-divers (Hare et al., 2013) where the pattern of cortisol reactivity (e.g., quick rise and reduction) is distinct (Meyer et al., 2015). Therefore, it is anticipated that age and experience might play a greater role in the pattern of cortisol reactivity than in the magnitude of the cortisol response.

One of the key challenges in investigating the psychosocial effects of sport competition on the cortisol response is separating cortisol secretion due to emotional stress or due to physiological demands of the exercise. Exercise intensity influences blood glucose levels and declining blood glucose levels elicit the hypothalamus to secrete the corticotrophin releasing hormone (CRH). CRH triggers the release of the adrenocorticotropic hormone (ACTH) which activates the adrenal cortex to release cortisol (Brooks et al., 1996). The release of cortisol in this mechanism supports homeostasis of blood glucose levels by stimulating gluconeogenesis from amino acids and mobilizing free fatty acids (FFA) from adipose tissue (Brooks et al., 1996). Cortisol secretion with the aim of mobilizing energy sources is therefore independent from experiencing psychosocial stressors and is mainly a function of exercise intensity. Indeed, Jacks et al. (2002) identified that blood glucose significantly decreased whilst salivary cortisol significantly increased after 59 minutes of high intensity exercise in comparison to rest and low-intensity exercise. This finding is supported by the conclusion from Kudielka et al.

(2009) that both maximal physical exercise and sustained exercise above 70% of the VO2max will significantly increase cortisol concentrations compared to moderate exercise intensities. Therefore, to examine psychosocial stress and cortisol reactivity in sport competition, it is important to investigate the anticipatory stress response in contrast to exercise induced changes. If pre-competition cortisol has a possible influence on sport performance, it is of interest to examine the magnitude of this anticipatory cortisol response. By means of a meta-analysis it is possible to aggregate the results of other studies and to examine the influence of moderating variables on the anticipatory cortisol response before competition.

2.1.1 Aim and hypothesis

The aim of this meta-analysis is to aggregate the findings of studies on the effects of anticipating competing in real sport competitions on the salivary cortisol concentration of athletes. It was hypothesized that the anticipation to compete in competitive sports results in an increase in salivary cortisol from baseline levels. Laboratory studies (Engert et al., 2013) have identified that the anticipatory cortisol response is higher when assessed closer to exposure to the stressor. Therefore, it was hypothesized that the anticipatory salivary cortisol response is higher when assessed closer to the start time of sport competition. In addition, the aim is to examine the effects of the moderator variables gender, experience and competitive level on the anticipatory salivary cortisol response.

2.2 Method

2.2.1 Search strategy

The electronic databases PubMed, PsycINFO, SPORTDiscus and Scopus were searched separately on the 26th of October 2015 with an updated search on the 1st of March 2017. To obtain studies on the anticipatory cortisol response to competitions, the following combination of key words were used in the search strategy “hydrocortisone” OR “cortisol” AND “anxiety” OR “stress” OR “arousal” AND “sports” OR “sport” OR “athlet*” OR “match” OR “competition” (see appendix 1). No cut-off publication date was used and the reference lists of included studies were examined for additional studies that could meet the inclusion criteria. The search strategy and reporting of the meta-analysis was conducted according to the PRISMA Statement (Moher, Liberati, Tetzlaff, Altman, & Group, 2009).

2.2.2 Inclusion/exclusion criteria

Initially the title and abstract of the identified studies were examined; studies were included when they met the following criteria: 1) a study must include participants that were competing in a real sport competition in contrast to an experimentally created sport competition 2) free (unbound) cortisol concentrations were determined from saliva samples 3) saliva samples were collected before the sport competition 4) time-matched resting or baseline samples were collected on a non-competition day. Studies were included when published as a full-text manuscript in a peer reviewed journal and written in English. Whenever there was the suggestion from the title and abstract that a study could meet the inclusion criteria, the full text of the study was examined. Studies were excluded when 1) baseline samples were not collected, collected on the day of the sport competition or not time-matched 2) saliva flow was stimulated via a reagent (e.g., citric acid) 3) performing arts or extreme sports (e.g., sky-diving, scuba diving, rock climbing) were used as manipulation. The process of confirming studies for inclusion and exclusion was performed independently by two reviewers (KvP and JL, research assistant) at study and study outcome level. Disagreements between reviewers were resolved via a discussion of eligibility criteria and study information to reach consensus. To reduce the chances of bias within the meta-analysis studies were examined when there was the suggestion that cortisol responses were derived from the same sample of participants but reported in multiple studies (n=2). When this occurred, the publication was chosen that included 1) the largest amount of information (e.g., timing, mean cortisol concentration) or 2) the highest number of participants.

2.2.3 Data extraction

Full text manuscripts were examined and the following information was extracted and coded

Participant characteristics: number of participants, gender, years of playing experience, level of competition, team or individual sport and type of sport.

Cortisol: mean salivary cortisol concentration and standard deviation before competition and the mean salivary cortisol concentration and standard deviation from the rest samples.

Cortisol collection: exact time of saliva collection, exact time of competition, before or after midday saliva collection, saliva collection method, saliva cortisol assay method.

For effect size estimates of individual studies, the standardized mean difference (Cohen's d) was used based on the rest and pre-competition cortisol concentration divided by the population pooled standard deviation. The effect sizes were calculated with the formula

$$\mathrm{d} = \frac{(M_{cortcomp} - M_{cortrest})}{\sqrt{(SD^2_{cortcomp} + SD^2_{cortrest})/2}}$$

When the concentration of cortisol in saliva and/or the standard deviation were not fully presented numerically within the study, the following procedure was used to derive the effect size. 1) When data was presented in figures numerical information was derived from digitizing figures with figure digitizing software (Plot Digitizer, Version 2.6.8, http://plotdigitizer.sourceforge.net) (Silva et al., 2012; Tsafnat et al., 2014) 2) When this was not possible, inferential statistical information were used to calculate the effect size.

3) When 1 and 2 were not possible the authors were contacted and asked for the relevant information.

If studies reported multiple relevant effect sizes (e.g., gender differences), separate effect sizes were extracted. When repeated measures or games were presented, an average of the pre-competition and/or baseline cortisol concentration and variation were used to derive one effect size. For example, Carre et al. (2006) and Cuniffe et al. (2015) reported the cortisol response in the same participants in home and away games; as game location was not considered a moderating variable, the average from the two competitions was used. In other instances, where comparisons were made between winners and losers (Filaire et al., 2001) an average of the cortisol concentrations and variation was created to derive one effect size. When cortisol was assessed on multiple time points from the same participants, the saliva collection time point closest to the start of the competition was used.

2.2.4 Statistical analysis

A random effects meta-analysis was used for all analysis as heterogeneity across studies was expected (Borenstein, Hedges, Higgins, & Rothstein, 2011). All analysis were conducted in the Comprehensive Meta-analysis programme (CMA, version 3.3.070). The calculated standardized mean effect sizes were corrected for small sample bias with the Hedge J correction with the formula

$$g = d * \left(1 - \left(\frac{3}{4 * df - 1}\right)\right)$$

The resulting Hedges' g effect sizes were used in the analysis. Initially, Z statistics were used to examine whether the overall effect was significantly different from no effect. The Q-statistic and I^2 measure were used to examine the heterogeneity within the sample of effects sizes. Based on a significant Q statistic and an I^2 measure of above 75%, heterogeneity was assumed and subsequently the effects of moderating variables were analysed. The influence of moderating variables on the cortisol response was assessed via sub-group analysis of variance. To assess the association between continues variables (e.g., saliva collection time) and salivary cortisol, meta-regression was conducted (Borenstein et al., 2011). A *p* value of .05 was used in all analyses to indicate significant differences.

2.3 Results

2.3.1 Study selection

From the identification process, the titles and abstracts of 1593 studies were screened (figure 2.1). Within screening, studies were predominantly excluded due to the focus on health, immune functioning or over-training. The full-text of the remaining studies were examined for eligibility where 24 studies met the inclusion criteria. The reference lists of the identified 24 studies resulted in two more studies that were eligible for inclusion (Bateup, Booth, Shirtcliff, & Granger, 2002; Edwards & Kurlander, 2010). Data of these 26 studies were extracted. From one study, Thatcher et al. (2004), it was not possible to retrieve all results, so this study was excluded. The analyses were conducted on 25 studies.

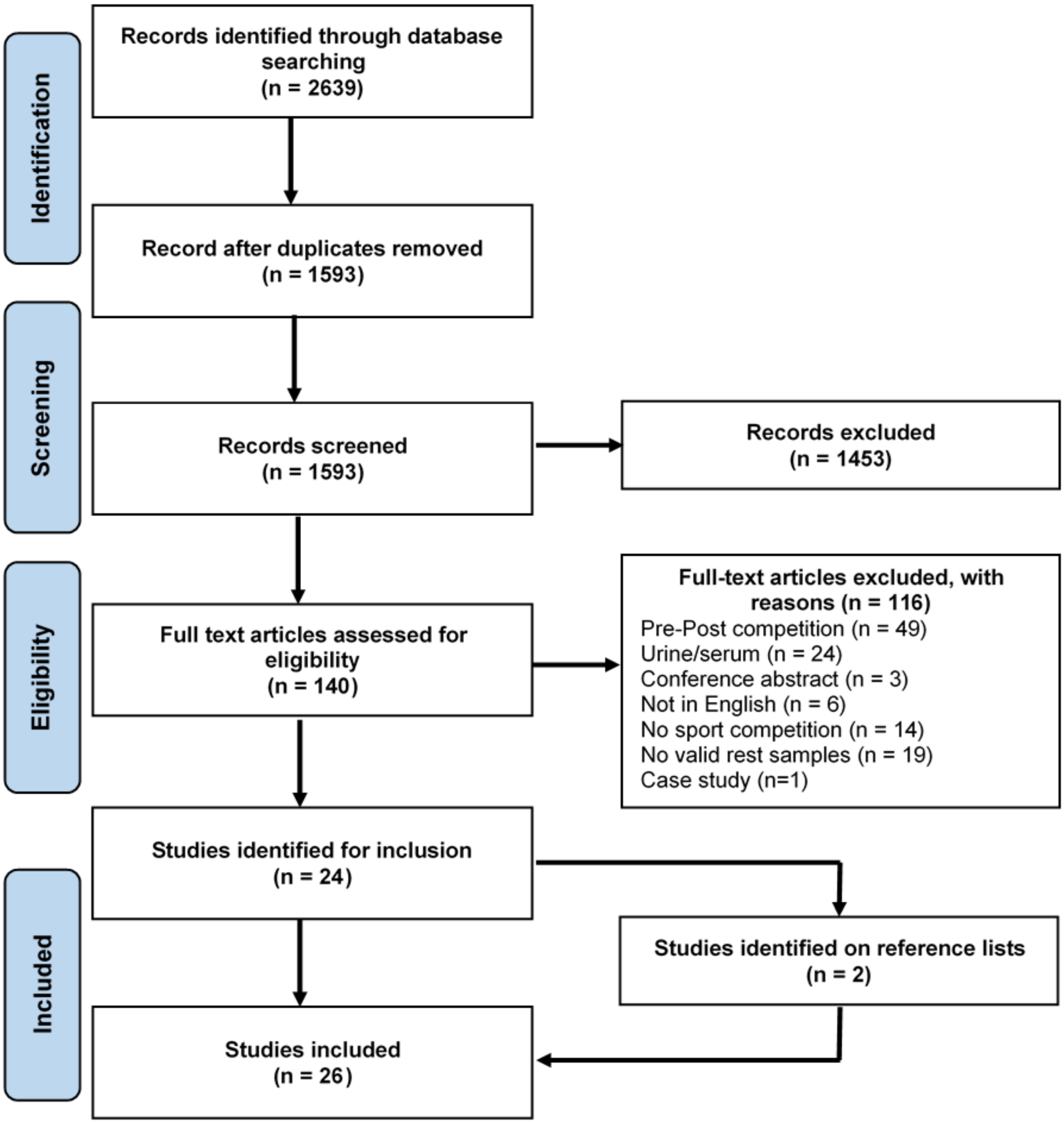

Figure 2.1 Flow chart of search strategy.

2.3.2 Study Characteristics

An overview of the characteristics of the 25 included studies with 27 effect sizes and 348 participants is presented in table 2.1. The average sample size (±SD) was 13±5 participants per study with an average participant age of 23.7±6.8 years. The proportion of male athletes in the sample was 67%. Female athletes accounted for 27% and two studies (6% of the participant sample) used a mixed gender population. In total, 11 effect sizes with a total of 170 participants came from studies using athletes from team sports where the other 16 used athletes from individual sports.

Table 2.1 Descriptive characteristics of studies included in the meta-analysis

	Study characteristics						
Study	N	Gender	Age	Type	Level	Time of day	Collection time
Alix-Sy et al. (2008)	18	m	24.6	T	NAT	PM	90
Balthazar et al. (2012)	8	m	27.8	I	NAT	AM	0
Bateup et al. (2002)	17	f	20	T	NAT	PM	15
Booth et al. (1989)	6	m	19	I	NAT	PM	15
Carre et al. (2006)	14	m	18.2	T	NAT	PM	45
Coelho et al. (2010)	17	m	23.6	I	INT	PM	30
Cook et al. (1989)	8	m	35.1	I	REG	AM	0
Cuniffe et al. (2015)	15	m	26.2	T	INT	PM	90
Diaz et al. (2013)	11	m	21.5	I	NAT	PM	120
Doan et al. (2007)	8	m	20.3	I	NAT	AM	45
Edwards et al. (2010)							
Team	15	f	--	T	REG	PM	95
Individual	13	f	--	I	NAT	PM	10
Elloumi et al. (2008)	20	m	25.8	T	INT	PM	180
Filaire et al. (2004)	12	f	12.5	I	NAT	PM	5
Filaire et al. (2001)	18	m	22.2	I	REG	PM	5
Haneishi et al. (2007)	10	f	20.2	T	NAT	PM	30
Iellamo et al. (2003)							
Male	4	m	26.7	I	NAT	AM	0
Female	4	f	26.7	I	NAT	AM	0
McKay et al. (1997)	15	m	22.5	I	NAT	--	20
McLellan et al. (2011)	17	m	24.2	T	NAT	PM	30
Moreira et al. (2014)	12	m	19	T	NAT	PM	30
Oliveira et al. (2009)	23	f	24.2	T	NAT	PM	30
Piacentini et al. (2015)	5	m	47	I	NAT	AM	0
Robazza et al. (2012)	9	m	29.1	T	NAT	PM	0
Salvador et al. (2003)	17	m	19.4	I	REG	AM	40
Sperlich et al. (2012)	17	m	22	I	NAT	--	2
Yuan et al. (2008)	16	mix	15.4	I	REG	AM	45

Note. N = number of participants in the study; Gender: m = male athletes, f = female athletes, mix = mixed gender population; Type: T = team sport, I = individual sport; Level: REC = Recreational, REG = Regional, NAT = National, INT = International; Time of day: AM = Morning, PM = Afternoon; Collection time: Saliva collection time in minutes before start of the competition. Dashes indicate that data was not available.

2.3.3 Publication Bias

To assess bias towards including published studies with significant results over unpublished studies with non-significant results in the meta-analysis Egger's test of funnel plot asymmetry was used to calculate the fail-safe N in the overall cortisol response. Assessment of publication bias indicated a fail-safe N of 734 studies to reduce the overall effect to below p=0.05.

2.3.4 The anticipatory cortisol response to competition

The random effects meta-analysis identified a large and significant cortisol response in athletes anticipating sport competition (g=0.85, SE=.16, 95%CI 0.54-1.17, Z=5.38, p<.001). Large heterogeneity was observed among studies (Q=108.38, p<.001) indicating variance in anticipatory cortisol response that could be explained by moderating variables (figure 2.2).

Study name	Hedges's g	Standard error
Alix-Sy et al., 2008	3.621	0.532
Balthazar et al., 2012	0.895	0.472
Bateup et al., 2002	0.333	0.329
Booth et al., 1989	0.338	0.491
Carre et al., 2006	-0.335	0.359
Coelho et al., 2010	0.430	0.331
Cook et al., 1987	1.053	0.482
Cuniffe et al., 2015	0.676	0.356
Diaz et al., 2013	3.317	0.636
Doan et al., 2007	-0.046	0.445
Edwards et al., 2010 (1)	0.835	0.362
Edwards et al., 2010 (2)	0.174	0.368
Elloumi et al., 2008	0.437	0.307
Filaire et al., 2004	1.319	0.425
Filaire et al., 2001	3.341	0.506
Haneishi et al., 2007	0.030	0.409
Iellamo et al., 2003 (1)	1.685	0.665
Iellamo et al., 2003 (2)	0.780	0.635
McKay et al., 1997	0.364	0.348
McLellan et al., 2011	0.337	0.329
Moreira et al., 2013	1.020	0.407
Oliveira et al., 2009	0.670	0.293
Piacentini et al., 2015	-0.123	0.507
Robazza et al., 2012	1.147	0.467
Salvador et al., 2003	0.874	0.343
Sperlich et al., 2012	1.289	0.362
Yuan et al., 2008	0.400	0.339
	0.854	0.159

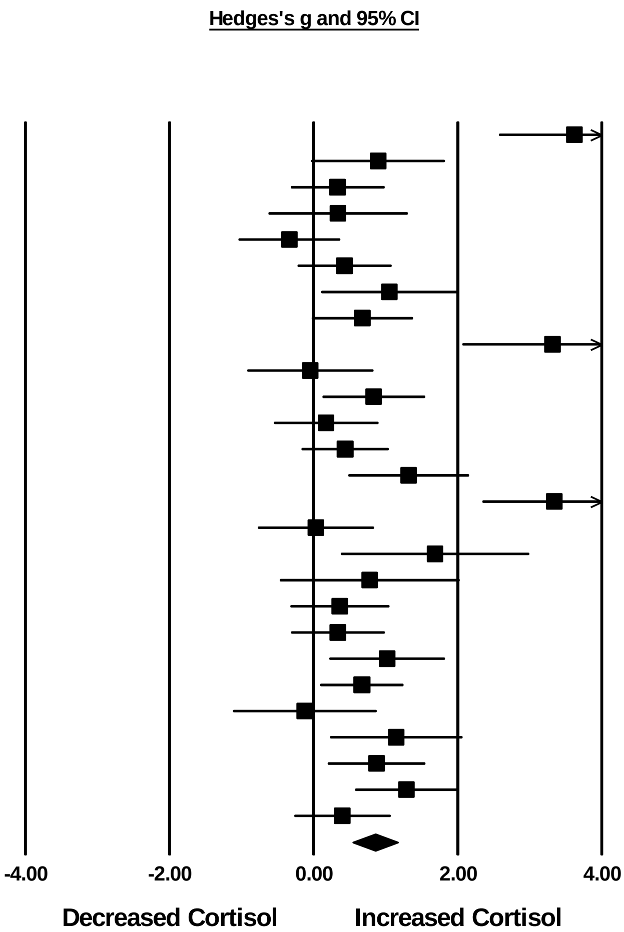

Figure 2.2 Forest plot of the included studies average effect sizes by weight.

2.3.5 The effect of gender on the anticipatory cortisol response to competition

A significant anticipatory cortisol response was identified in the 19 studies with male athletes (g=1.05, SE=.20, 95%CI 0.65-1.44, Z=5.19, *p*<.001). In contrast, the anticipatory cortisol response of the 7 studies with female athletes was not significantly different (g=0.58, SE=0.32, 95%CI -0.042-1.20, Z=1.83, *p*=.07). There was no significant difference in the anticipatory cortisol response between males and females (Q(1)=1.54, *p*=.21) where the true differences between males and females falls in the range of -.24 and 1.24 (figure 2.3).

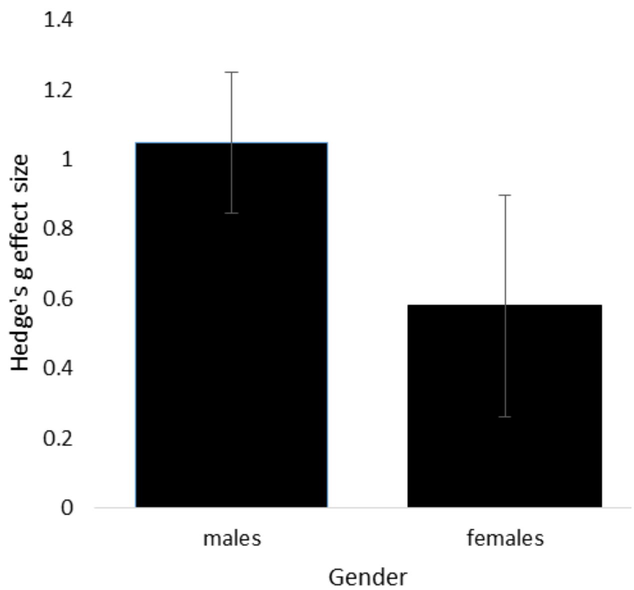

Figure 2.3 Hedge's g effect sizes of cortisol reactivity in male and females.

2.3.6 The effect of team and individual sport on the cortisol response

A significant anticipatory cortisol response was identified in studies that used athletes who competed individually (g=0.94, SE=.21, 95%CI 0.53-1.36, Z=4.42, *p*<.001) as well as in athletes competing in team sports (g=0.74, SE=.25, 95% CI 0.26-1.22, Z=3.02, *p*=.003). There was no significant difference between athletes of these two modes of sport (Q(1)=0.39, *p*=.53).

2.3.7 The effect of level of competition on the cortisol response

A comparison between athletes competing at regional, national or international level identified that there was no significant difference between these type of athletes on the anticipatory cortisol response (Q(2)=1.03, *p*=.60, figure 2.4). Athletes competing at national level (g=0.84, SE=.20, 95%CI 0.44-1.24, Z=4.16, *p*<.001) and at regional level (g=1.11, SE=0.35, 95%CI 0.42-1.78, Z=3.17, *p*=.002) showed a significant anticipatory cortisol response in comparison to no response. However, athletes competing at international level did not demonstrate a significant anticipatory cortisol response (g=0.51, SE=0.47, 95%CI -0.40-1.43, Z=1.10, *p*=.23).

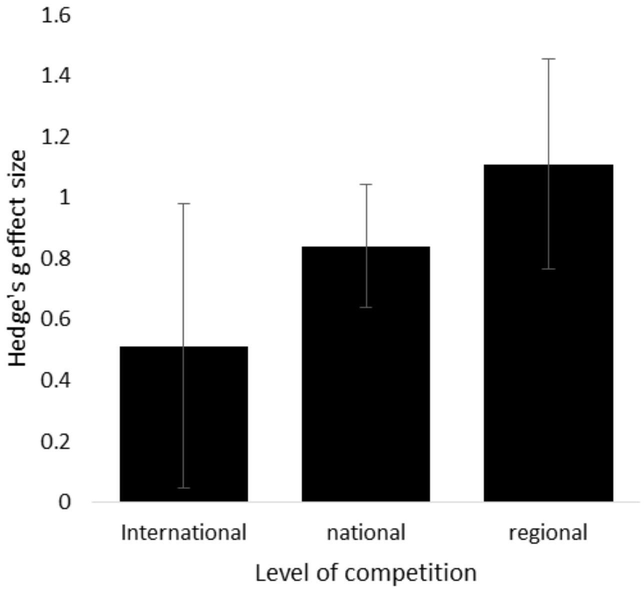

Figure 2.4 Hedge’s g effect sizes of cortisol for international, national and regional athletes.

2.3.8 The effect of time of competition (am versus pm) on the cortisol response

To examine the influence of the circadian rhythm of cortisol on the anticipatory cortisol response, studies with sport competition in the morning and afternoon were compared. No significant difference in cortisol reactivity between morning and afternoon competition was identified (Q(1)=0.59, *p*=.44) where both morning (g=0.66, SE=0.32, 95%CI 0.037-1.28, Z=2.08, *p*=0.04) and afternoon studies (g=0.95, SE=0.20, 95%CI 0.54-1.36, Z=4.57, *p* <.001) showed a significant anticipatory cortisol response.

2.3.9 Collection time before competition and cortisol response

To test the effects of data collection time before competition on the cortisol response, a random effects regression analysis with hedge’s g effect sizes versus the data collection time point before competition was conducted. To create a homogenous sample, 5 effect sizes were excluded from this analysis as these samples were all collected a minimum of 45 minutes later than the 22 included effect sizes (see table 2.1). All 22 effect sizes collected saliva samples up to 45 minutes before the start of the competition. The collection time of saliva samples before competition significantly related to the anticipatory cortisol response (Q(1)=6.85, *p*=.009). The negative slope of the regression line indicated a larger anticipatory cortisol response when samples are collected closer to start of the competition (see figure 2.5). In addition, goodness of fit was significantly different (Q(20)=46.16, *p*<.001, R^2 of 0.29), indicating that 29% of the variance in cortisol effect can be explained by saliva collection time.

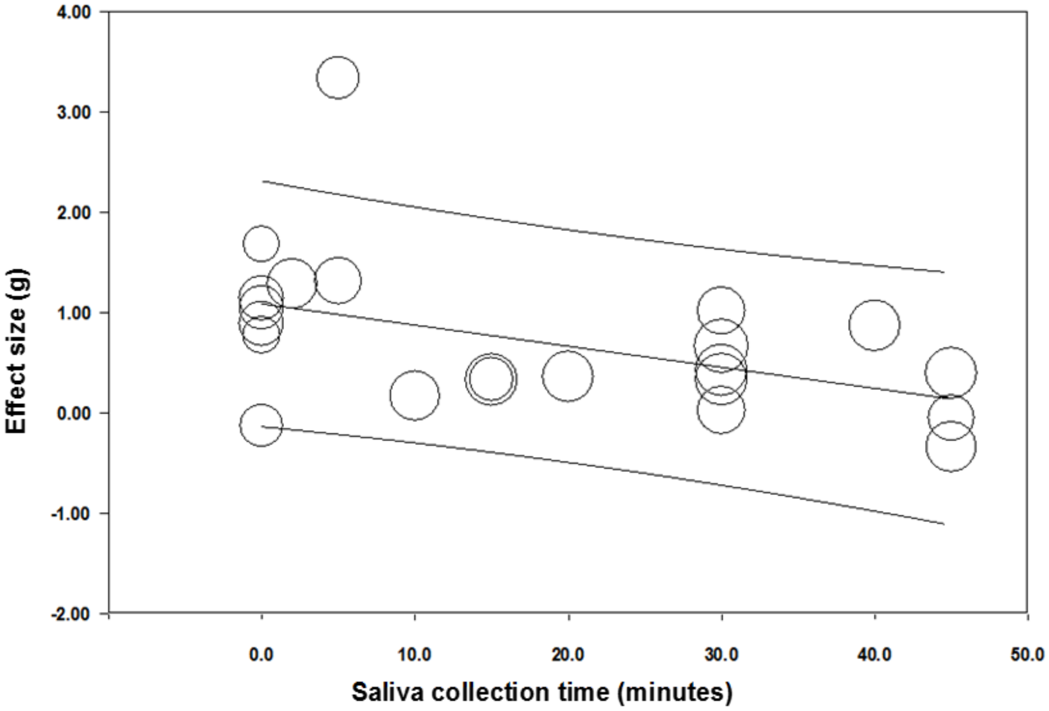

Figure 2.5 Hedge's g effect sizes of the cortisol response of competition against saliva data collection time before competition. Larger value on Y axis denotes that samples were collected a longer time from the start of competition.

2.4 Discussion

The main aim of the meta-analysis was to identify whether the anticipation to participate in sport competition influences the salivary cortisol concentration. To examine this, the results of 25 studies that measured salivary cortisol before sport competition, in addition to a time-matched baseline sample on a control day were combined. Effect sizes were calculated based on the change in cortisol concentration from time-matched baseline to before sport competition. The combined results identified the presence of a significant anticipatory cortisol response before competition (g=0.85) where the anticipatory cortisol response is significantly greater when assessed closer to the start of competition. These findings further support the presence of anticipatory stress response in athletes before sport competition. However, large heterogeneity between effect sizes from individual studies were identified, where the analysis of moderating variables (e.g., gender, type of sport) could not fully explain this large heterogeneity.

Hanton, Thomas and Maynard (2004) identified a significant increase in cognitive and somatic anxiety in the time leading up to competition. The findings of the current meta-analysis support Hanton et al. (2004) with the conclusion that there is also a significant increase in the biological stress response leading up to sport competition. The average anticipatory cortisol response of 0.85 corresponds to the cortisol response in laboratory based stress manipulations using the TSST, d=0.86 (Dickerson & Kemeny, 2004). However, the cortisol response before sport competition is lower than identified in extreme sports such as sky-diving (d=1.5 Deinzer et al., 1997). The positive effects of moderate cortisol concentrations on reaction time and inhibition of aversive stimuli is associated with moderate cortisol responses (d=1.0) reflecting a dosage of 5mg exogenous cortisol (Schwabe, Oitzl, Richter, & Schächinger, 2009; V. A. Taylor et al., 2011). In contrast, negative effects of cortisol through reduced inhibition of task irrelevant stimuli are related to large cortisol responses (d=1.4-d=3.0) reflecting a dosage of 10-40mg exogenous cortisol (Putman & Berling, 2011; Shields et al., 2015). Therefore, the identified anticipatory cortisol response of 0.85 before sport competition reflects moderate cortisol reactivity which prepares the athlete optimally for the psychological and physiological demands of competition.

2.4.1 Gender differences

Males had a significant anticipatory cortisol response but this was not identified in females. In addition, there was a strong indication that males experience a greater anticipatory cortisol response (g=1.05) than females before sport competition (g=0.58, p=.06, figure 2.3). This finding confirms previous results of gender differences in cortisol reactivity after exposure to psychological stress (Kudielka & Kirschbaum, 2005). Males tend to have a significantly greater cortisol reactivity both in anticipation and response to the TSST than females (Kirschbaum et al., 1992; Uhart, Chong, Oswald, Lin, & Wand, 2006). The findings in the current meta-analysis, further support this, where the absence of the anticipatory cortisol response and strong trend for males to show greater cortisol reactivity than females can be related to gender differences in the interpretation of psychological stressors. Psychological stressors related to challenges tends to stimulate HPA-axis activity more in males, where females show greater HPA-axis reactivity in social rejection paradigms (Stroud, Salovey, & Epel, 2002). The psychological stress associated with sport competition (e.g., performance failure, achievement challenges) reflects this challenged state, explaining the higher anticipatory stress response in males. One study in the analysis included a comparison between male and female athletes (Iellamo et al., 2003). Whilst a small sample size was used (3 females and 4 males) a greater increase in anticipatory cortisol was observed in males (2.7 fold increase) compared to females (1.6 fold increase). The findings that males show stronger emotional responses (e.g., cognitive - somatic anxiety) in anticipation to sport competition compared to females (Craft et al., 2003; Woodman & Hardy, 2003) are further supported by the indication that males also demonstrate a stronger anticipatory cortisol response to sport competition.

2.4.2 Team versus individual competition

Within team sports athletes interact and share responsibility to achieve goals related to successful sport performance. This cooperation offers opportunities for social interactions between athletes in preparation to and during competition. This shared responsibility to the outcome and opportunities for social interaction reduces cognitive and somatic anxiety responses before sport competition in team sport athletes in comparison to individual athletes (Craft et al., 2003; Terry, Cox, Lane, & Karageorghis, 1996). In addition, providing verbal social support during psychosocial stress tasks reduces the cortisol response in comparison to not receiving this support (Kirschbaum, Klauer, Filipp, & Hellhammer, 1995). Therefore, an analysis was conducted to identify whether athletes participating in team sports have a lower anticipatory cortisol response in comparison to individual athletes. Although the results indicate that both team (g=0.74, *p*=.003) and individual athletes (g=0.94, *p*<.001) demonstrate a significant anticipatory cortisol response, there were no differences between the team and individual athletes. This finding might be affected by the large variation in individual cortisol reactivity, resulting in large standard deviations of the included effect sizes. As previous studies identify differences in the emotional response between team and individual athletes, it is of interest to examine whether team and individual athletes differ in cortisol reactivity in experimental studies with a repeated measures design. For example, sports where athletes compete both individually and in pairs (e.g., tennis, golf) could be used to examine whether social influences of team sports affect cortisol reactivity.

2.4.3 Cortisol reactivity and level of competition

Studies were categorised into regional, national or international level based on the characteristics of the athletes and/or the sport competition to assess whether level of competition affected cortisol reactivity. Where both regional (g=1.1, p=.002) and national level competitors (g=0.84, *p*<.001) showed a significant increase in cortisol, this was absent in the international level competitors (g=0.51, *p*=.23). The absence of a significant cortisol response in international athletes could be related to the timing of collection of saliva samples, where studies with international athletes collected samples longer before the start of competition (30-180 minutes before) compared to studies with national or regional athletes. No significant differences between the three sub groups of level of competition were identified (*p*=.60). The categorisation of studies into level of competition, and not on the years of experience at this competitive level, might have affected these results. For example, Mellalieu, Hanton and O'Brien (2004) identified that the emotional response (e.g., cognitive anxiety) before sport competition was significantly lower in more experienced athletes compared to less experienced players. This finding is further supported by Kivlighan et al (2005) who identified that the anticipatory cortisol response in a created rowing competition was significantly lower in more experienced athletes compared to novices. The results of the analysis on the level of competition might be influenced by the level of experience of the athletes within the studies.

As playing experience at the assessed competition level was not reported in the majority of studies, it was not possible to analyse whether playing experience might affect the anticipatory cortisol response.

2.4.4 The effects of time of competition

Salivary cortisol follows a circadian rhythm, where following awakening an increase in cortisol is identified and during the day cortisol gradually decreases (Hucklebridge, Clow, & Evans, 1998). The lowest levels of cortisol are typically reported during the evening. To assess whether competing at different times of the day would affect the anticipatory cortisol response studies were separated into morning and afternoon. 7 studies assessed cortisol in the morning and 17 studies in the afternoon. Both morning (g=0.66, p=.04) and afternoon studies (g=0.95, p<.001) showed a significant anticipatory cortisol response. However, there was no indication that the anticipatory cortisol response was different between morning and afternoon studies (p=.44). Dickerson and Kemeny (2004) identified that morning studies have a small cortisol response in comparison to larger effect sizes in afternoon studies. The identified difference by Dickerson and Kemeny (2004) of 0.32 resembles the difference in the current analysis (0.29). The non-significant difference between morning and afternoon is possibly due to relative low number of effect sizes included in this analysis. Furthermore, the type of sport played was not controlled for. For example, different sports, played at different times of day were included in the analysis. Further research needs to consider whether the type of sport impacts cortisol measures. However, it is recommended that studies examining cortisol reactivity in sport recognise the influence of the awakening response. For example, it is likely that the cortisol awakening response influenced baseline or pre-competition cortisol concentration in studies with early morning competition (e.g., golf, Doan et al., 2007).

2.4.5 Cortisol reactivity and collection time

The results from the regression analysis on the effect size of the anticipatory cortisol response and data collection time before sport competition identified that the anticipatory effect of cortisol is increased when samples are collected closer to the start of competition (p=.009, figure 5). This finding further supports previous studies on the emotional response to sport competition. Hanton et al (2004) identified that cognitive and somatic anxiety significantly increased from 2 hours before competition to 30 minutes before competition. Although studies on the cortisol response to laboratory psychosocial stressors tend to show an increase in cortisol in reaction to the application of the stressor (Dickerson & Kemeny, 2004), it is suggested that some people have an anticipatory cortisol response to the stressor (Engert et al., 2013). In addition, if studies included in this meta-analysis collected saliva cortisol on two time points before competition (Balthazar et al., 2012) the time point closer to the start of the competition resulted in the highest cortisol effect size. Therefore, if studies want to examine the role of the anticipatory stress response in athletes, it is important to consider collecting saliva samples as closely as practically possible to the start of the competition.

2.4.6 Limitations and recommendations

Whilst the meta-analysis identified a clear anticipatory stress response, some limitations in the analysis need to be acknowledged. As the analysis focussed on the differences between studies, the variability in cortisol responses within studies was not assessed. The effects sizes derived from these studies were influenced by the large variation in cortisol reactivity between participants within a study, as demonstrated through large standard deviations. This large variation within an included effect size influenced the ability to identify significant differences in the analysis of moderating variables. Although the moderating variables should be able to explain some of this variation within studies, the combination of the variation in reactivity within studies and the number of included effect sizes affected the examination of these moderating variables. In addition, several methodological elements that could explain the variation between and within studies should be acknowledged. As all studies collected samples before real sport competition it is likely that salivary cortisol concentration might have been affected by a warm-up and/or the consumption of food and beverages. These factors can positively skew the concentration of salivary cortisol (Kudielka et al., 2009).

2.4.7 Conclusion and recommendations

The results of this meta-analysis identifies that athletes who anticipate to compete in a sport competition have a significant anticipatory salivary cortisol response. Female athletes and athletes competing at international level do not demonstrate this significant anticipatory cortisol response. However, the analysis of moderating variables did not identify significant differences within categories of moderating variables. Therefore, the findings of this study highlight that the previously identified emotional response in anticipation to sport competition is accompanied by a distinctive physiological stress response via activation of the HPA-axis. Male athletes and athletes competing at a lower level demonstrate to have a significant increase in cortisol in anticipation to participate in real sport competition. Hence it is recommended that for the examination of the influence of cortisol on perceptual-motor skills in sport psychology male participants are used as these are likely to experience greater HPA-axis reactivity to stressors related to sport competition.

Chapter 3: General Method

3.1 General methods

The previous experimental chapter identified the cortisol response in anticipation to sport competition and the factors which influence this response. Based upon these results, the following laboratory based experimental chapters were designed. This general method chapter describes the methodological approaches undertaken in the laboratory based experimental chapter in this thesis, that rely on experiments that were conducted in the Sport and Exercise Science laboratories at Anglia Ruskin University, Cambridge, UK. This general methods chapter provides an overview of the participants used in these studies and the stress manipulation the participants experienced. In addition, details of equipment, variables and data processing of measures of performance, visual attention, emotions and biological stress that were collected from the participants are discussed. Details of the specific methodology of the experiments, the procedures and statistical analysis are presented within the individual laboratory based experimental chapters.

3.2 Participants

Within the laboratory based experimental chapters, participants from the student population at Anglia Ruskin University volunteered to participate. Male participants were recruited as males tend to demonstrate stronger cortisol reactivity than females in social evaluative situations (Kirschbaum et al., 1992; Kudielka & Kirschbaum, 2005). In addition, the findings from the meta-analysis, presented in experimental chapter 2, identified that males experience a significant cortisol response in anticipating to participate in real sport competition, where this was absent in females. Hence, an experimental stress manipulation related to self-presentation would increase the likelihood of observing activation of the HPA-axis when using male participants. With using males, potential confounding effects of the stage of the menstrual cycle, which has been known to affect HPA-axis reactivity, would be eliminated (Kudielka, Buske-Kirschbaum, Hellhammer, & Kirschbaum, 2004).

All participants were right handed, had self-reported normal or corrected to-normal vision (via contact lenses) and were specifically selected as being novice golfers with no golf or golf putting experience. Novice participants were specifically recruited as novices experience stronger stress responses when executing fine motor skills in comparison to experts (Nibbeling et al., 2012). Within the experiments in chapters 4 and 6 saliva was collected to assess the endocrine response. Saliva has a small but possible risk of transmission of infectious disease. Therefore, participants who believed they had a serious infectious disease (such as HIV or hepatitis) were asked not to participate in the study, for safety of the researcher. This was specified within the recruitment of participants and verified via a questionnaire before commencing the study. Participants who regularly smoked or who had diabetes were excluded due to their effects on salivary cortisol concentrations. Regular smokers have significantly higher cortisol levels than non-smokers (Steptoe & Ussher, 2006) and people with diabetes have a blunted cortisol profile (Bruehl, Wolf, & Convit, 2009). All participants provided written informed consent before participation and all experiments received institutional ethical approval. The tenants of Declaration of Helsinki were observed.

3.3 Golf putting equipment

Within the experimental chapters in this thesis participants putted golf balls on a 6.0 m long by 0.75 m wide straight and flat indoor putting mat with a Stimp reading of 2.75 m (LinksPutt, Perth, UK). A standard size hole (10.8 cm diameter, 5.0 cm depth) or circular target (10.8 cm diameter, 0.0 cm depth) was positioned 0.9 m from the end of the putting mat and 0.375 m from either side. Participants putted regular sized golf balls (EZ distance balls, Nike) with an 87 cm Anser style cavity type golf putter (Dunlop Classic putter, Dunlop, UK) from a distance of 3.5 m from the hole/target. Further details on the positioning of task-irrelevant information on the putting green is presented in the individual experimental chapters.

3.4 Performance

Although outcome measures of sport performance provide detail on the ultimate outcome of the event (e.g., did you win or lose), it does not explain how this outcome was achieved. Changes in the outcome of performance can rely on external factors, other than the individual performer (e.g., a goal keeper in soccer penalty kicks). Therefore, the experimental chapters in this thesis examined both the outcome and accuracy of performance in addition to the process of achieving this outcome (e.g., movement execution of the task) as well as the variability in both the accuracy of performance and movement execution.

3.4.1 Performance outcome

Performance outcome was assessed in chapter 5 as the number of putts holed (e.g., landed in the hole). Within chapter 6, a circular target area (the size of a standard hole used in golf) was used to ensure that both length and accuracy of the putt could be aligned to movement execution (e.g., forward velocity and club head angle at ball impact).

3.4.2 Performance accuracy

In addition to performance outcome, studies often measure performance accuracy to assess performance, as this provides a more continuous measure of performance and is more sensitive to identifying small perturbations in performance compared to outcome measures. Performance accuracy in aiming tasks can be described as the distance from the end location of an object (e.g., ball) in comparison to the intended end location or target. This accuracy measure can be described in units of distance. For example, Mullen et al. (2005) and Cooke at al. (2010; 2011) measured performance accuracy in a golf putting task via the end location of the ball in respect to the hole in x-y coordinates. This measure, referred to as mean radial error (MRE), was used as an accuracy measure and calculated via the equation:

$$MRE = (Xc^2 + Yc^2)^{1/2}$$

Xc is the mean distance from the hole in the longitudinal direction (X) of the putt, Yc the mean distance in the medial-lateral direction (Y) of the putt. In the subsequent experimental chapters, the MRE of individual putts was averaged for multiple trials within conditions (see further details in experimental chapters).

3.4.3 Performance variability

Where the MRE provides a measure of performance accuracy of the end location of the ball, it does not provide a measure of the variability (or consistency) in multiple attempts. The variability in performance can explain how consistent individuals are in outcome accuracy over multiple trials. The combination of MRE and a variability measure of performance can further highlight the interaction between consistency and accuracy (see figure 3.1). The bivariate variable error (BVE) was used to assess performance variability in the end location of the ball with respect to the hole (Hancock, Butler, & Fischman, 1995), with the equation:

$$BVE = \left\{(1/k)\sum[(Xi - Xc)^2 + (Yi + Yc)^2]\right\}^{1/2}$$

Where, Xc is the mean distance from the hole in the longitudinal direction of the putt, Yc medial-lateral to the direction of the putt. Xi and Yi are the ith trial and k is the number of trials. The difference between performance accuracy and variability is represented visually in figure 3.1 below.

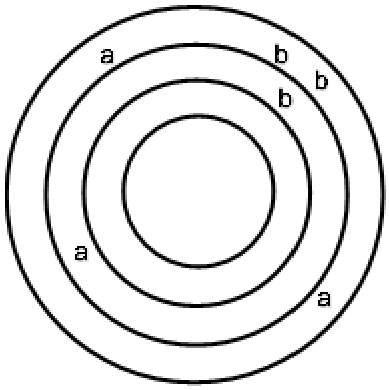

Figure 3.1 Performance accuracy versus variability. Representative end locations of a ball for participant a and b for three shots. Although the mean radial error (e.g., average distance from the hole) is similar between participants a and b, the variability in performance (BVE) of participant b is lower due to the smaller dispersion between the end ball locations.

The end location of the ball was recorded at 25Hz with a digital video camera (Canon Legria HF R28E, Tokyo, Japan) positioned 2.5 m above the centre of the hole to derive performance accuracy and variability. Bitmap images from the end ball location on the green were created from the video with a video editing tool (VLC media player, version 2.0.8, Boston, US). The X and Y position of the end location of the ball relative to the centre of the hole, in cm, was derived from bitmap images with Image Digitizing software (Image Digitizing Software Ver. 2.30b1; Omaha, Nebraska, USA). The known width of the green, and distance from centre of the hole to end of the green, were used in the calibration of the images.

3.4.4 Movement execution

Within this thesis, movement execution was assessed through the kinematic analysis of the club head during the putting stroke with a three-dimensional motion analysis system (Codamotion, Charnwood Dynamics Ltd, Leicestershire, UK). The Codamotion system uses small infrared light emitting markers powered by a small rechargeable battery unit. The active marker sends out a unique infrared signal that can be linked to its position on the golf putter. The infrared signal is recorded by Cartesian Optoelectronic Dynamic Anthropometer units (CODA, CX1, Charnwood Dynamics Ltd, Leicestershire, UK). A CX1 unit identifies the locations of the active marker in three dimensions via trigonometry based on the entry of the infrared signal at three locations at the CX1 units (see figure 3.2).

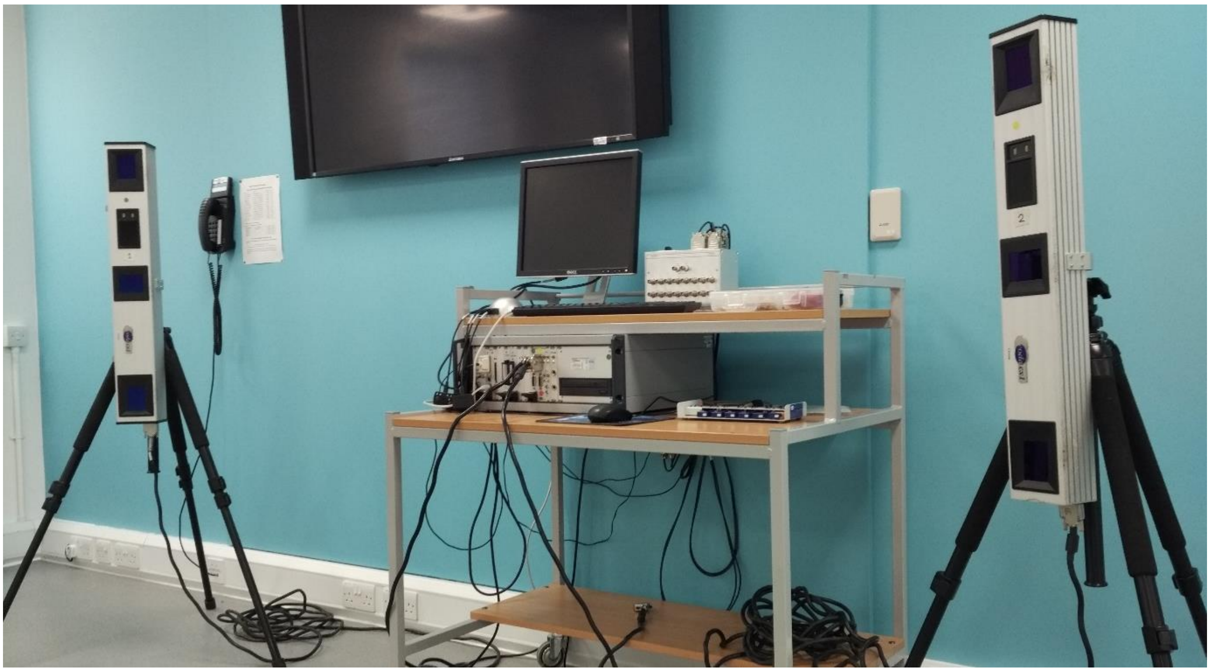

Figure 3.2 The Codamotion three-dimensional motion analysis system. With two CX1 units in the left and right side of the image.

On the CX1 unit, a high resolution sensor behind an array grid creates a shade of the infrared signal on the sensor to record the angle of entry of the signal. A combined analysis based on the location of the sensors on the CX1 units, the angle of the entry of the signal and recorded shade, identifies that exact location of the marker in the x (horizontal), y (adjacent) and z (vertical) plane. Two markers were positioned on either side of the rear of the club head and used to derive the kinematic profile of the club head during the putting stroke (see figure 3.3).

Figure 3.3 Golf putter with infrared light emitting markers. Attached to the club head, at the bottom left and right side, two infrared light emitting markers used to identify the orientation and position of the club head.

Although a single CX1 unit provides a viewing angle approaching 80°, two CX1 units were used to improve the accuracy and signal strength of the recording. Two CX1 units were positioned at a 45° angle behind the participant. Club head kinematics were collected at a high frequency of 400 Hz due to the short data collection period, ability to identify ball impact and to ensure that sampling frequency was at least double the frequency of the frequency of changes in positional data (Winter, 2009). Participants were instructed to align the club head against the ball, before starting the swing action. The phase from initiation of club head movement (start backswing) up to ball impact during the downswing was used to describe the putting movement. Ball impact was defined as the instance where the face angle of the club head passed the initial starting point in the forward (x) direction (see figure 3.4).

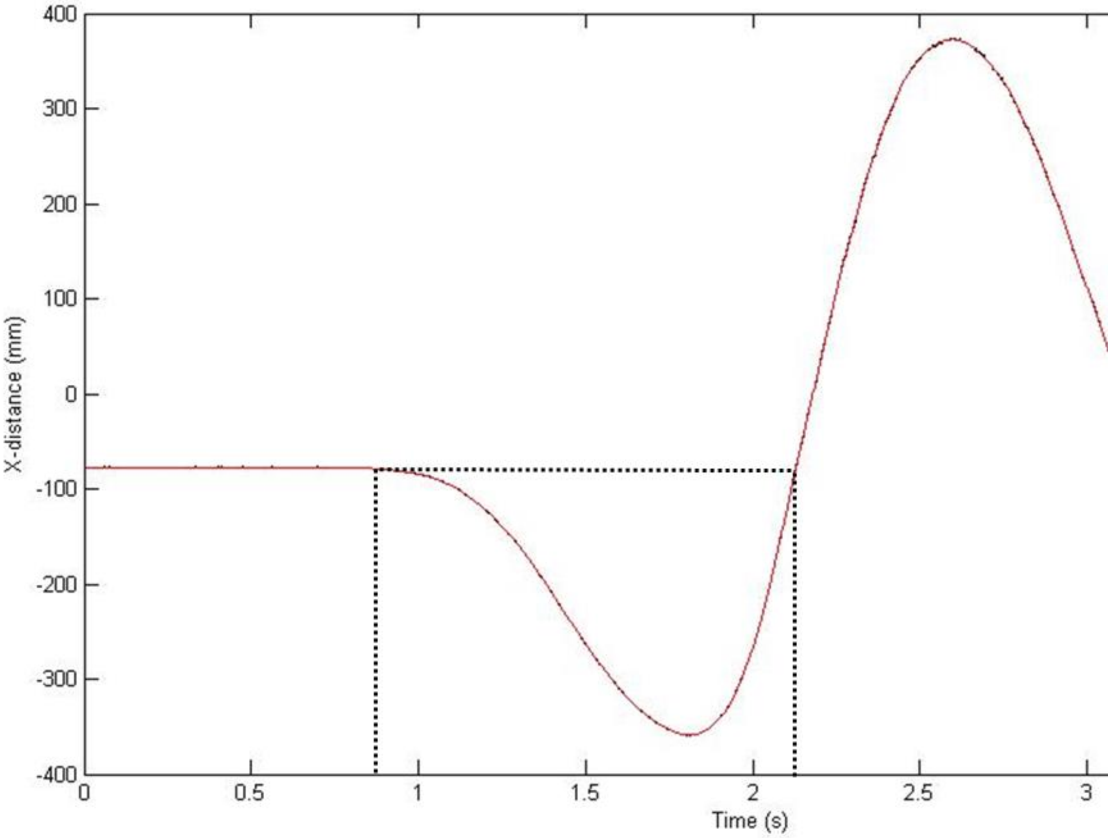

Figure 3.4 Example of club head displacement profile in forward direction. Red line shows the x (forward-backward) displacement of the putter. The dashed (black) lines indicate the initiation of the putter movement backswing (around 0.9 s) and downswing (around 1.8 s), to impact (around 2.1 s)

Noise within the raw kinematic data is expected due to electrical interference with a typical lower amplitude than the original data (Winter, 2009). Therefore, raw positional data was filtered with a low pass second-order Butterworth filter, where the lower frequencies of noise were removed without affecting the original signal. To determine the optimal cut-off frequency for the Butterworth filter a residual analysis was conducted in Matlab (R2009b, 7.9.0, The Mathworks, Inc., Natick, MA). From this a 12Hz cut off frequency was determined and used to filter the positional data in x, y and z direction (see figure 3.5) (Winter, 2009).

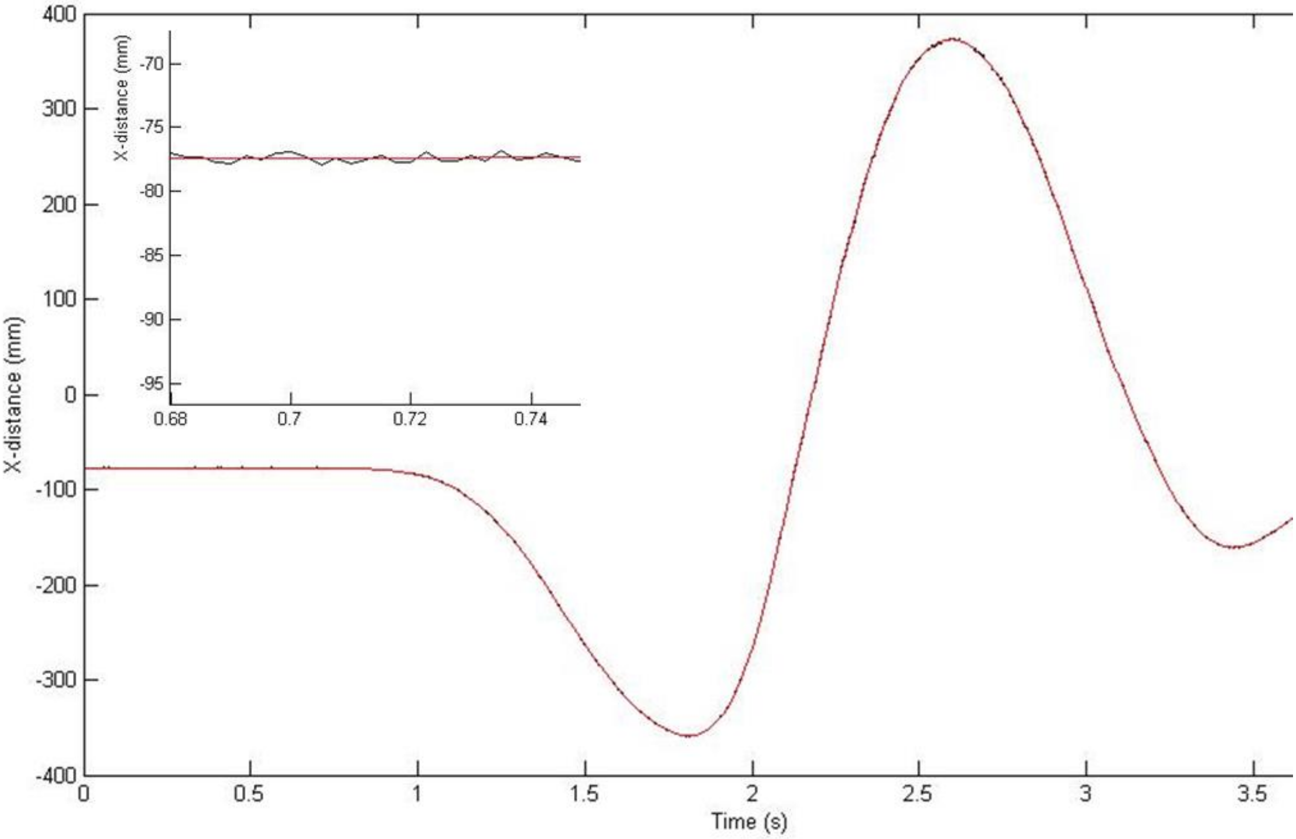

Figure 3.5 Effect of Butterworth filter on positional data of club head. Raw unfiltered data (black line) and filtered data with a cut off frequency of 12Hz (red line) of the forward displacement (X) of the club head. Insert: a zoomed section of the figure to illustrate the effect of Butterworth filter.

After the data was filtered, the x, y and z position of the two markers on the club head was analysed and transformed into performance variables with a bespoke programme written in Matlab (R2009b, 7.9.0, The Mathworks, Inc., Natick, MA, see appendix 2 for script).

The first derivative of the positional data was used to calculate the instantaneous velocity during putting movement. Variables derived from the execution of the putting action were separated into continuous variables and instantaneous variables.

Instantaneous variables: Club head face angle at ball impact is considered the key variable for putting direction, as 80% of the initial ball direction is accounted for by the club head face angle at ball impact (Karlsen et al., 2008). Club head face angle, at ball impact, was calculated from the difference in position of the markers in the x (forward)-direction at ball impact. The length of the golf putt is determined by ball speed and reflected in impact velocity of the club head, where impact velocity of the club head is affected by the length of the backswing (Delay et al., 1997). Hence, club head velocity at ball impact was identified as well as the maximum backswing displacement (length).

Continuous variables related to the movement were separated for the sections backswing and downswing. From the club head movement the average velocity during the downswing in x, y and z direction were calculated as well as total time to complete the putting action and backswing and downswing time.

The intra-trial variability of velocity (e.g., during a single putting movement) was expressed as the standard deviation of the average velocity during the downswing movement. This variability measure of velocity is also known as the instantaneous velocity deviation or speed variability and commonly used to describe intra-trial variability of velocity during fine motor skills (Hoogendam et al., 2014) and to describe variability in velocity in locomotor trajectories (Pham & Hicheur, 2009). Additionally, the standard deviation of the club head angle during downswing was used to describe the variability in club head angle during the downswing.

Variability between trials (e.g., in multiple attempts within a condition) in the putting movement of instantaneous measures (e.g., impact angle) was expressed as the variable error (VE) with the equation:

$$VE = \left\{(1/k)\sum\lceil(Xi - M)^2\rceil\right\}^{1/2}$$

Where Xi is the value of the variable (e.g., velocity at impact) for the i-th trial, k is the number of putts in the trial (e.g., 5) and M is the average value of the variable over the k trials. The variable error was used to describe the consistency of instantaneous variables over multiple trials (i.e., back swing length, total movement time, backswing time, downswing time, impact velocity and impact angle).

3.5 Eye tracking

A mobile eye tracker was used to measure visual search behaviour during the golf putting action, to identify visual attention in the experiments in chapters 5 and 6. Visual search behaviour was measured with a SMI mobile eye gaze registration system (IviewETG, SensoMotoric instruments Inc, Teltow; Germany, Ver. 1.0). The system consists of a pair of lightweight glasses with two infrared eye cameras and a HD scene camera. The SMI eye tracker measures the binocular direction of gaze (e.g., in both eyes) via the corneal reflection and the dark pupil principle. Within the lower part of the frame are two small infrared cameras projecting infrared light on the cornea of each eye. The reflection of the infrared lights are captured where the pupil will appear dark, due to the absorption and angular reflection of light from the fovea. The darker appearance of pupil is captured via a camera and translated to the directional position of the pupil within the scene camera. Therefore, the relative position of the centre of the eye with respect to the scene camera is used to determine the direction of gaze in the environment with a frequency of 30 Hz and a spatial resolution of 0.1° and gaze position accuracy of 0.5°. The glasses were connected with a USB cable to a laptop (Lenovo X220, Thinkpad, USA) positioned on a table behind the participant (chapter 5) or in a hip bag (chapter 6). The eye cameras have a gaze tracking range of 80° horizontally and 60° vertically where the high definition (HD) scene camera (1280x960 pixel, 24Hz) has a tracking range of 60° horizontally and 46° vertically. Wearing an eye tracker might affect the behaviour of the participant. However, Vickers and Williams (2007) found that wearing an eye tracker did not affect shooting accuracy in an aiming task, similar to a golf putting action in the area it subtends in the field of view. In addition, a study from our research group on the differences in total visual field when wearing an eye tracker, identified that the total visual field whilst wearing an eye tracker (113 ± 5°) was not significantly different from not wearing an eye tracker (125 ± 0°) (Timmis et al., 2017). Data was collected with Iview ETG software (Ver. 2.0, SMI, Teltow, Germany). The eye tracking glasses were calibrated with a three point calibration in the sagittal plane at a 2 meter distance from the participant. Pilot work demonstrated that a calibration from 2m distance was optimal to maintain accurate direction of gaze to nearby

AOIs (e.g., golf ball) as well as further away (e.g., hole). Calibrating to the ball or hole would result in an inaccurate direction of gaze to either the nearby, or further away, AOIs respectively. The calibration was checked every 10 putts.

3.5.1 Visual search behaviour analysis

Visual search behaviour collected with an eye tracker can be analysed with different methods. In general there are two approaches;

1) Eye movement analysis (based on dispersion), where no eye movement indicates that the point-of-gaze is constant in an area in the environment.
2) Gaze location; where the point-of-regard (POR) on an AOI is used to determine visual search behaviour. This implies that a constant POR on an AOI indicates a fixation of gaze on this location.

The key difference between these two approaches is related to the functionality of data analysis. An analysis based on eye movements can be done semi-automatically by means of dispersion algorithms specifying the thresholds of eye movement to identify fixations and saccades (e.g., with the Begaze analysis software, SMI, Teltow, Germany). The identified fixations from the algorithm are mapped onto AOIs. In contrast, an analysis based on gaze location needs to be completed frame-by-frame to identify POR at each instance in time. Within the chapters of this thesis a frame-by-frame analysis based on gaze location was used due to the dynamic environment.

Within a dynamic environment (static observer-moving AOI or observer moving-static AOI) there is a limit to the application of eye movement based analysis methods for the following reason; a smooth pursuit of a moving AOI typically coincides with eye movement. This eye movement prevents the detection of a fixation, despite the constant point-of-regard on the object. However, adopting an analysis approach based on POR on an AOI requires careful interpretation particularly with larger AOIs. Within a large AOI (e.g., the green) it is likely that POR will be directed to different elements of the AOI (e.g., a saccade from one location of the green to a new location on the green). The frame-by-frame analysis of POR should take this relative movement of the POR within the AOI into account. Hence, it is pertinent that the selection of AOIs should be carefully considered in the frame-by-frame analysis of eye tracking data, in addition to the relative movement of the POR within the AOI.

Within the frame-by-frame analysis the characteristics of visual search behaviour are typically described in the number of times and the total time the POR is directed to an AOI. These features of visual search behaviour are calculated after the frame-by-frame mapping of POR on AOIs. The static POR on an AOI indicates that the AOI is being visually attended.

3.5.2 Dwell versus fixation eye tracker data analysis

With the adopted approach of the frame-by-frame analysis, of POR on AOIs, it is possible to analyse visual search behaviour with a fixation, as well as a dwell, based approach. A fixation based approach, commonly used in the sport and exercise sciences, considers a minimum amount of time an AOI should be attended to be considered a feature of visual search behaviour. Within sport and exercise science a POR on an AOI of a minimum of 100ms (Murray & Janelle, 2003), 120ms (Williams, Davids, Burwitz, & Williams, 1994; Wood & Wilson, 2010) are used, whereas a 200ms fixation threshold is adopted in reading studies (Salthouse, Ellis, Diener, & Somberg, 1981). In contrast, gazes below 100ms, 120ms or 200ms would be included in a frame-by-frame dwell based approach. The exact reasoning behind adopting a 100-120ms cut-off is not specified within the aforementioned publications. However, it is likely to relate to 1) fixations, based on eye dispersion, rarely last less than 100ms (Salvucci & Goldberg, 2000) 2) the suggestion that stimuli cannot be identified when attended to less than 100ms and 3) the low sampling frequency of the portable eye trackers at the time the research was conducted. Studies provide evidence that humans can correctly identify the presence and characteristics of objects if these are present in the visual field from 17 to 50ms (de Wit, Masters, & van der Kamp, 2012; Hoshiyama, Kakigi, Watanabe, Miki, & Takeshima, 2003; van Rullen & Thorpe, 2001) highlighting the important contribution of short dwells in extracting visual information from the environment. This is reflected in the important distinction between identifying visual stimuli and reacting to visual stimuli. The first is examined by presenting images of short duration to participants for correct identification, where identification is possible from 17-50ms. The latter measures motor-response time, typically the elapsed time from presenting visual stimuli to motor-response (e.g., button press), where the minimum duration is 160ms. Although portable eye trackers develop rapidly, their sampling frequency (e.g., 30-60hz) is far below that of some stationary eye trackers (typically around 1000hz). Hence, limiting the ability to assess small eye movements (micro-saccades/express saccades) used in the exploration of visual scenes, due to the large intervals between consecutive samples. Within pilot work undertaken in the current thesis using the portable eye tracker, it was identified that participants typically interrupted a saccade from ball to hole (or vice versa) to direct their POR laterally to attend to features positioned midway on the green, between ball and hole/target (see https://tinyurl.com/y9gjkpom), similar to the observations by Tatler, Hayhoe, Land and Ballard (2011). The absolute time visually attending to these features was typically below the 100ms minimum to identify a fixation and would be excluded from a fixation based analysis. Hence, based on the ability of humans to identify objects below the 100ms fixation threshold and the observed visual search behaviour in pilot work, a dwell based analysis (not requiring any minimum fixation time to be achieved) of visual search behaviour was conducted. The differences between a fixation and dwell based approaches to analyse visual search behaviour were compared by processing data with both approaches. The differences between approaches were minimal when prominent AOIs (e.g., ball, hole) were compared. Dwells at these AOIs are typically more than 100ms. However, the shorter periods of time when POR was directed to potentially distracting features in the environment were typically missed in a fixation based analysis

The dwell based frame-by-frame analysis eye-tracking data was completed offline with Begaze analysis software (SMI, Teltow, Germany Ver. 3.4). Based on Vickers (1992) the AOIs Ball, Hole, Green, Putter, in addition to task-irrelevant information in the form of Blocks were used. Each golf putt was analysed from the first gaze on the ball after the putter head was aligned to the ball, up to the instance of ball impact. Each frame was mapped onto the identified AOI within the software (see figure 3.6).

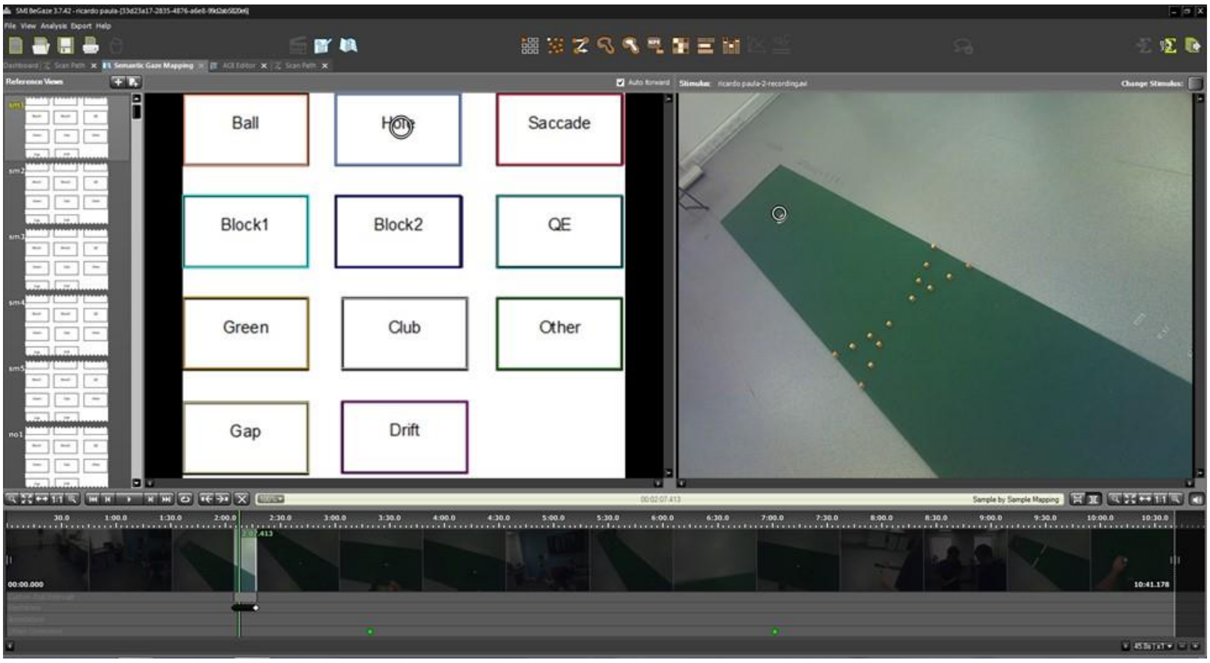

Figure 3.6 The Begaze eye tracking analysis software. The video of the POR in the environment is presented on the right side. The coding window on the left side is clicked to indicate what POR is gazed at for each frame.

The Begaze software allows for off-line, post-data collection, adjustment of the calibration. Hence, during the data analysis the calibration was adjusted when the calibration check, after 10 putts, identified a gaze off-set.

Following the frame-by-frame mapping, trials were exported into text files where the AOI attended to in each frame was present. To characterise visual search behaviour a bespoke programme was written in Matlab (R2009b, 7.9.0, The Mathworks, Inc., Natick, MA) to process the text files (see appendix 3 for script). In short, each text file is processed in the Matlab script to analyse, for each AOI:

-The absolute and relative number of times the AOI was attended.

-The absolute and relative total length of time looking at the AOI.

-The average length of a dwell.

-The absolute and relative QE period. The QE period was defined as the length of the last dwell at the ball before the onset of putting movement (e.g., start of the backward movement of the putter) until the club head made contact with the ball in the downswing (Vickers, 1992).

-Scan rate defined as the number of dwells per second.

Although visual search behaviour is calculated both as absolute and relative to trial length, it is predominantly presented as relative to trial length in the thesis. It is common to present the analysis of visual search behaviour as an absolute measure of time, instead of relative to trial time, particularly when individual variables of visual search behaviour are presented (e.g., QE). To identify differences in the distribution and direction of visual search behaviour in different experimental conditions it is more appropriate to express variables of visual search behaviour relative to trial length, as trial length typically changes under different experimental conditions. For example, in a climbing experiment, Nieuwenhuys et al. (2008) identified, on average, a 38% increase in fixation duration on key AOIs (handholds, wall), under high anxiety compared to low anxiety. Concurrently, climbing time (e.g., trial length) significantly increased by 36% under high anxiety compared to low anxiety conditions. An expression of visual search behaviour relative to trial length could highlight whether the experimental condition influenced the distribution of visual attention over the AOIs, irrespective of changes in trial length.

3.6 The biological stress response

Within experimental chapters 4 and 6 the endocrine response of participants was assessed to provide an objective measure of the amount of stress experienced. The biological stress response is coordinated by the central nervous system (CNS) by means of activation of two main systems: the hypothalamic-pituitary-adrenal (HPA) axis and the sympathetic nervous system (SNS). Both HPA-axis activation and SNS activity were assessed, minimally invasive, via biomarkers in saliva.

3.6.1 SNS activation

Activation of the SNS leads to the release of norepinephrine (NE) into serum from the adrenal medulla of the adrenal gland, as well as neurotransmitter, from noradrenergic neurons in the CNS and SNS. Both SNS activation and NE triggers neuropsychological responses (i.e., increase heart rate, pupil dilation and perspiration) in support of the fight and flight response. The assessment of these physiological responses can be invasive for the participants and interpretation of responses is challenging where the validity of direct assessment of NE in saliva is poor due to the weak associations between serum and saliva NE (Granger et al., 2007; Neukirchen & Kienbaum, 2008). However, several authors identified that sAA activity increases following exposure to psychological and physiological stress (Nater et al., 2005; van Stegeren, Rohleder, Everaerd, & Wolf, 2006). Alpha-amylase is an enzyme, produced in the salivary glands and its general function is to assist with the digestion of complex sugars. In response to SNS activation, NE release acts on the salivary glands to increase the protein-to-saliva ratio by releasing proteins (Nater & Rohleder, 2009). Hence, an increase in NE results in an increase of proteins in saliva. In this process, the enzyme α-amylase is released from the salivary glands into the oral cavity. This finding led studies to examine the relationship between NE, neuropsychological measures of SNS activation and sAA. Early work of Chatterton, Vogelsong, Lu, Ellman and Hudgens (1996) demonstrated a strong associations (r = 0.64) between serum concentration of NE and sAA during high intensity exercise with a low correlation (r =0.17) in a psychological stress task. A review by Nater and Rohleder (2009) identified a large variation in studies reporting the correlation between NE and sAA. However, when including other measures of SNS activation their conclusion was that "secretion of sAA are clearly sympathetic in nature" (Nater & Rohleder, 2009, p.492). This conclusion is further supported by more recent findings from Thoma, Kirschbaum, Wolf, & Rohleder (2012) where sAA reactivity significantly explained NE changes (r= 0.33) in a psychosocial stress task. Therefore, sAA can be considered a valid measure to assess SNS activation, and was used in chapters 4 and 6 of this thesis.

3.6.2 HPA-axis activation

From an evolutionary perspective, the HPA-axis is activated in reaction to stressful events to initiate a set of physiological responses to prepare the individual for challenges and threats in the environment (Boyce & Ellis, 2005; Kudielka et al., 2009). Both physiological and psychological stressors can activate the HPA-axis. Psychosocial stressors and negative emotional responses, activate the central nervous system via connections between prefrontal cortex, limbic structure and hypothalamus. This process results in activation of the HPA-axis, where the hypothalamus releases the corticotropin releasing hormone (CRH) and consecutive secretion of adrenocorticotropin hormone (ACTH). ACTH activates the release of cortisol into the blood stream from the adrenal cortex on the kidneys, before cortisol diffuses into saliva via the salivary glands.

3.6.3 Saliva collection

Saliva samples were collected with SalivaBio Oral Swabs (SOS, Salimetrics, State College, PA, USA). The collection system consists out of a synthetic oral swap (the SOS) for the passive collection of saliva and a swab storage tube (see figure 3.7). The use of a synthetic foam material for the oral swab, compared to previous cotton material, has the advantage that more saliva can be extracted from the swab after collection whilst reducing the chance of absorbance of sAA and cortisol within the cotton (Beltzer et al., 2010; Strazdins et al., 2005).

Figure 3.7 The SalivaBio oral swab and swab storage tube.

In contrast to cortisol, saliva flow rate influences sAA expression. With a longer saliva collection time, more saliva is sampled, hence the procedure of saliva collection was standardized. Unstimulated saliva was collected sublingual (e.g., the participants placed the oral swab underneath the tongue) for two minutes. A sublingual collection was used as the synthetic SOS has a constant absorbance volume sublingual in 1-3 minute collections, in contrast to linear increases in saliva volume in submandibular locations (Beltzer et al., 2010). Saliva was collected for 2 minutes, as sAA activity reduces in saliva samples when collection is longer than 3 minutes (Beltzer et al., 2010). This, combined with the stability of saliva flow between 1 and 3 minutes, highlights that a 2 minute collection is most appropriate for sAA assessment with the synthetic SOS collection method (Beltzer et al., 2010). To correct for small fluctuations in the 2 minute collection an exact saliva collection time was recorded from insertion and removal of the swab. Participants were instructed not to move the oral swab in their mouth or chew on the swab. In addition, as immune assay procedures of saliva are affected by the biochemical content of saliva, participants were asked to abstain from consuming fluids and food, with the exception of water, for at least 60 minutes before saliva collection. In addition, on arrival in the laboratory, around 15 minutes before collection, participants were asked to rinse their mouth with water.

3.6.4 Saliva collection timing

Reactivity of sAA and cortisol, following exposure to stress, has distinct kinetic patterns (Engert et al., 2013). Firstly, cortisol follows a circadian rhythm with peaks measured on awakening and the lowest levels of cortisol measured in late evening (Hucklebridge et al., 1998). Therefore, to warrant homogeneity in saliva sampling and cortisol assessment, all data collection was completed in the afternoon. Secondly, peak salivary cortisol levels tends to be measured around 15-20 minutes following experiencing stress (Engert et al., 2013). This delay relates both to slower HPA-axis response to stress as well as a delay from release at the adrenal cortex to diffusing into the saliva glands. In contrast, SNS activation, with sAA release, has a quicker response pattern partly due to direct influence of SNS on protein release from the salivary glands, in addition to an in general faster SNS activation in response to stress (Nater & Rohleder, 2009). A typical increase in sAA can be observed within 2 minutes following exposure to stress (Engert et al., 2013).

A saliva collection protocol was developed to capture these differences in reactivity patterns between sAA and cortisol following exposure to stress. Saliva was collected on arrival in the laboratory (-30 minutes before the trial), immediately before the trial (-1), immediately after the trial (+1 minute), and at 20 minutes and 40 minutes post trial. These timings are expected to identify a peak in sAA immediately after the trial, and a peak for cortisol at 20 minutes after the trial (Engert et al., 2013). Further details of this collection protocol, and amendments to this, are presented in the individual chapters.

3.6.5 Saliva storage

All saliva samples were stored on icepacks, before being stored at -80 °C, typically within 2 hours following collection. Previous studies have demonstrated that the cortisol concentration in saliva, stored in a SOS, stays constant for a week at room temperature (20 °C) and several months when stored below 0°C (Kirschbaum & Hellhammer, 1999). Similarly, sAA concentration stays stable at room temperature (20°C) and several months at -80°C (O'Donnell, Kammerer, O'Reilly, Taylor, & Glover, 2009). Both salivary cortisol and sAA are not affected by repeated freeze-thaw cycles (Kirschbaum & Hellhammer, 1999; O'Donnell et al., 2009). Hence, the adopted method of saliva storage ensured that both salivary cortisol and alpha-amylase concentrations remained stable before further analysis.

3.6.6 Saliva analysis

The analysis of saliva samples for cortisol and AA concentrations were typically conducted within 1 month of collection. Although salivary cortisol concentration is not affected by flow rate of saliva, AA is affected by flow rate. Therefore, all saliva samples were weighed before analysis. The SOS were thawed and centrifuged at 1500 g for 15 minutes to separate the saliva from the SOS. This procedure assures that the majority of saliva was removed from the swab and is preferred over a manual expression method.

Salivary cortisol concentrations were determined with a high sensitivity cortisol Enzyme-Immunoassay kit (Salimetrics, State College, PA, USA) with a range from 0.012 $\mu g \cdot dL^{-1}$ to 3.0 $\mu g \cdot dL^{-1}$. The assays were run in duplicate, for the purpose of quality control, with a Tecan evo 150 robotic liquid handler (Tecan Group Ltd., Männedorf, Switzerland, see figure 3.8). 25 μL of saliva from each collected sample was pipetted into the appropriate wells of the plate, in addition, 6 known cortisol concentrations, zero concentration and cortisol controls were pipetted into the wells. Following adding 200 μL of conjugate control to each well, the plate was mixed and left to incubate for 1 hour, washed 4 times before adding a stop solution according to manufacturer procedures. The optical density of the plate was read out with a Sunrise absorbance Microplate Reader (Tecan Group Ltd., Männedorf, Switzerland). Light with a wavelength of 450nm, with a filter correction at 490nm, shined into the wells and the plate reader determined the percentage of light absorbed in the samples and the known concentration standards. A standard curve was produced from the know concentrations and the cortisol concentration in the unknown samples was interpolated from this regression line. sAA concentration was determined with a Salivary α-Amylase kinetic enzyme assay kit (Salimetrics, State College, PA, USA). In brief, saliva samples were diluted to 1:200 with the α-Amylase diluent from which 8 µL of controls and diluted saliva samples were added to wells on a microplate with a Tecan evo 150 robotic liquid handler (Tecan Group Ltd., Männedorf, Switzerland, see figure 3.8). With the use of a Biohit 1200µl multichannel pipette, 320 µL of α-Amylase substrate, containing 2-chloro-p-nitrophenol linked with maltotriose was added to the wells containing the controls and diluted saliva samples to instigate the kinetic enzyme assay. The enzyme activity results in a colour change, which was assessed spectrophotometrically at 405nm on a Sunrise absorbance Microplate Reader (Tecan Group Ltd., Männedorf, Switzerland) at 60 and 180 seconds. The change in colour over the two measurement points indicates concentration of AA in saliva and is derived from the control measurements of known concentrations of AA.

Figure 3.8 The Tecan Evo 150 robotic liquid handler used to complete the enzyme assay to assess salivary cortisol and amylase concentration.

3.7 Pressure manipulation

The experimental chapters in this thesis rely on exposing participants to a pressure manipulation. Within chapter 5 a repeated measures design was used where performance, performance execution and visual search behaviour in a golf putting task under a low-pressure condition were compared to a high pressure condition. Within chapter 4 and 6 participants were only exposed to the high pressure condition.

Low pressure: The participants were informed that the low pressure condition was used to gather a baseline score for their putting performance, movement execution and visual search behaviour. Participants completed these putts individually, in the presence of two researchers. To maintain motivation participants were informed that their putting performance would be recorded and was used to assess their golf putting ability in comparison to other participants (Chamberlain & Hale, 2007). However, participants were instructed that these scores would not be revealed to other participants, nor would it count towards their chance to win a monetary reward. No other manipulation was imposed.

High Pressure: The high pressure condition consisted of procedures identified by Baumeister and Showers (1986) incorporating self-presentation and motivational stimuli in the form of financial incentives. Financial incentives, as monetary rewards, are often used in pressure manipulations (Cooke et al., 2010; Hardy et al., 1996; Wilson et al., 2009) but not always (W. Land & Tenenbaum, 2012). Within chapter 5, participants were informed that the top three performers (e.g., lowest average mean radial error score) on the putting task would win a cash monetary reward of £50, £25 and £10 respectively. Due to the increase in the number of participants in chapters 4 and 6, the top four performers could win larger prizes of £75, £50, £25 and £10, to ensure comparable chances to win a prize. Previous studies have demonstrated that smaller monetary rewards (e.g., £15), in combination with other manipulations, are successful in inducing anxiety (Masters, 1992) where the offered monetary incentive in this study is comparable to other studies, $50 (Chamberlain & Hale, 2007), £50, (Wood & Wilson, 2010), £50, (Moore, Vine, Cooke, Ring, & Wilson, 2012). The monetary rewards were directly related to a social evaluation of putting performance. Within the laboratory there was a leader board presented on a video screen, with the names and performance (i.e. MRE) of 12 participants, either from the current study or from a previous pilot study. Participants were informed that their performance scores would be added to the leader board and shared with all other participants. Only 12 participants were ever presented on the leader board. Following each block of 5 putts, participants were directed to the score board and advised that they had to improve their putting score to maintain a chance of winning price money. Within a comparison of pressure manipulations, Mesango, Harvey & Janelle (2011) identified that self-presentation components (e.g., audience and/or video recording of participants) have a stronger effect on anxiety than motivational components (e.g., offering monetary rewards). Although the leader board presents a source of pressure related to self-presentation, this can further enhanced by including a “live” audience, providing direct social evaluation of performance (Chamberlain & Hale, 2007; Hasegawa et al., 2013) and/or a video camera recording the behaviour of the participant. An audience of four people was present in the high pressure condition. The audience was positioned towards the sides of the putting green, near the hole/target, to allow for direct evaluation of putting performance and to ensure that the audience was visible to the participant. Although the audience was in line-of-sight to the participants, visual search behaviour was only directed to the audience in-between putts and not during the preparation or execution of the putt. The audience were instructed to verbally and negatively evaluate the putting performance of the participant between putts, but not during the movement execution. Comments such as “that was a terrible shot” and “try to keep the ball on the green this time” were developed from the ideas of Law, Master, Bray, Eves and Bardswell (2003). Prior to the study, the audience were provided with a script with ideas of key phrases to use and practiced using them in a consistent manner. The audience were instructed not to use discriminatory or offending phrases. In addition to the audience, a video camera was directed towards the participant. The participants were informed that their putting technique was recorded and rated by a golf coach.

3.8 Psychometric measures

Within the experimental chapters of this thesis several self-reported measures of emotional states and appraisal of the pressure manipulation were used. The used questionnaires varied within the experimental chapters due to the different aims. Further details of which questionnaires were used are discussed in the individual chapters.

3.8.1 Trait anxiety

Trait anxiety was measured with the 20 item Spielberger Trait anxiety inventory (STAI-T, Spielberger, Gorsuch, & Lushene, 1970). Participants rated, on a 4 point Likert scale, how they generally feel. Questions such as, “I feel satisfied with myself” were rated from “almost never”, “sometimes”, “often” to “almost always”. The scores on this trait anxiety inventory range from 20-80 and were calculated by adding individual items. Within the original development of the scale several items, more associated with the assessment of depression, were removed, resulting in the 20 item version. The reported internal consistency range from 0.72 to 0.96 (Barnes, Harp, & Jung, 2002). The validity of the STAI-T has been extensively examined, identifying that the STAI-T is a valid instrument to assess general negative affect (Balsamo et al., 2013).

3.8.2 State anxiety

State anxiety was assessed with a modified Competitive State Anxiety Inventory-2 (CSAI-2, (Martens et al., 1990) immediately before the start of the golf putting task. The CSAI-2 is composed out of 27 questions on a 4 point Likert scale. Participants rated the experience of symptoms of somatic and cognitive anxiety from “Not at all” to “Very much so”. Additionally, a directional rating of the expected facilitative or debilitative effects, of the symptoms of anxiety, on performance was completed. A 7 point Likert scale varying from -3, very debilitative-negative, to +3, very facilitative-positive, was included (Jones & Swain, 1992). Validity of the CSAI-2 has been questioned by Lane, Sewell, Terry, Bartram and Nesti (1999), particularly with regards to the high inter-correlations between the two anxiety components. However, the inclusion of the directional component is suggested to improve the validity of the measurement of anxiety with the CSAI-2 (Jones & Swain, 1992). A limitations of the CSAI-2 is that the combination of the intensity and directional rating increase the length of time to complete the questionnaire and makes it impracticable to complete the questionnaire during the trial (e.g., in-between putts). Shorter questionnaires, as the Mental Readiness Form (MRF-Likert), (Krane, 1994), and rating scales such as the Anxiety Thermometer, (Houtman & Bakker, 1989) are used to allow participants to quickly identify the intensity of anxiety. The MRF-Likert is a 3-item questionnaire with single item subscales to measure cognitive anxiety (“my thoughts are”), somatic anxiety (“my body feels”) and self-confidence (“I am feeling”). The MRF-Likert was used in this thesis due to its convergent validity with the CSAI-2; inter-correlations of .68 to .76 were identified between MRF-Likert and CSAI-2 (Krane, 1994). Participants were asked to rate the questions on an 11 point Likert scale with the anchors *calm-worried*, *relaxed-tense*, and *confident-scared* for cognitive anxiety, somatic anxiety and self-confidence, respectively. The MRF exists in different forms, the MRF-Likert is different from the MRF-3 in that the MRF-3 uses truly bipolar items (e.g., worried-not worried) where the MRF-Likert uses more contrasting poles (e.g., calm-worried). The MRF-Likert was used as it has higher inter-correlations with CSAI-2 than the MRF-3 on the anxiety constructs (Krane, 1994).

3.8.3 Stress and arousal

To assess more general forms of stress and arousal the 34 item Stress Arousal checklist (SACL: Mackay, Cox, Burrows, & Lazzerini, 1978) was used. The SACL is commonly used to measure state stress and arousal in relation to biological indicators of stress (Thorn, Hucklebridge, Evans, & Clow, 2009). Within SACL participants were asked how they felt at that moment in response to a single statement (e.g., fearful) by indicating “definitely”, “slightly”, “undecided” or “definitely not”, on 18 items related to stress and 16 items related to arousal. The rating of these items were transformed into a scoring system from 0 to 3. Scores on the arousal construct could vary between 0 and 48 and 0 to 54 for stress, where higher scores indicate increased arousal and stress respectively. The SACL originally contained 4 constructs of measurement (including a negative and positive measure for both constructs), however, a factor structure analysis completed by Fisher and Donatelli (1987) highlighted improved validity of the SACL by only examining the two constructs, arousal and stress, compared to separating this into positive and negative constructs. The SACL was only used concurrently with participants providing a saliva sample in chapter 4.

3.8.4 Coping

There is evidence that approach and avoidance behaviour are characteristics of the adopted coping strategies during the completion of a stressful task. To assess coping strategies on the avoidance and approach continuum a questionnaire was developed based on Coping Style Inventory for Athletes (CSIA) and the Coping Style in Sport inventory (CSSI) (Anshel & Kaissidis, 1997; Anshel, Kang, & Miesner, 2009). Following a discussion with Mark Anshel (personal correspondence, October 2013) questions were selected that best described the coping strategies that were applicable to the golf putting task. The participants rated their use of avoidance and approach coping strategies on 16 questions based on a 5 point Likert scale varying from “very untrue” to “very true”. The concurrent validity of the CSIA has low, albeit significant correlations, with existing non-sport coping inventories, due to the differences in the phrasing of questions in the competitive sport setting (Anshel & Kaissidis, 1997). However, high construct validity of the CSIA was established by Anshel and Kaissidis (1997) by comparing the responses to hypothetical scenarios of avoidance and approach behaviours. Therefore, the CSIA is an appropriate measure to distinguish between approach and avoidance behaviours. In addition, both the CSIA and CSSI, where the questions were derived from, have acceptable Cronbach's alpha internal consistency scores varying from 0.68 to 0.84 (Abedalhafiz, Altahayneh, & Al-Haliq, 2010; Anshel et al., 2009).

3.8.5 Challenge and Threat

Within the evaluation of the demands to successfully complete tasks under high pressure conditions, it is suggested that participants can evaluate the situation as either a challenging or threatening experience. The theory of challenge and threat states (TCTSA, Jones, Meijen, McCarthy, & Sheffield, 2009) highlight that challenge states will develop with high levels of self-confidence to succeed in the task as well as high perceived control and approach behaviour over the task. In contrast, low self-confidence and perceived control in combination with avoidance behaviour, should elicit a threat state. Studies successfully developed distinct paradigms to create challenged or threating states and provides support for the conclusion that threat states negatively influences visual attention and performance in a golf putting task (Moore et al., 2012). Experiencing threat and challenge states warrant further exploration, particularly in studies examining the effects of anxiety on sport performance (Vine et al., 2016). A recently developed and validated questionnaire, the Challenge and Threat in Sport Scale (CAT-Sport) allows athletes to successfully evaluate the experience of challenge and threat in anticipation to sport competition (Rossato, Uphill, Swain, & Coleman, 2016). However, the CAT-Sport assesses challenge and threat, as the outcome of the evaluation, in anticipation to sport competition. For athletes, the sport competition is a familiar environment, where the expected situational changes in demands can be evaluated a priori. Within the current study participants were not familiar with the situational factors of the activity (e.g., they were novice in respect to golf putting and the pressure manipulation), hence a priori evaluation of the task, and experience of challenge and threat, was not deemed to be appropriate. Therefore, an adjusted version of the CAT-Sport was developed to assess challenge and threat retrospectively (e.g., following completion of the task). In personal communication with the author who developed the CAT-Sport (Dr Claire Rossato) a rewording of questions was completed to allow for CAT-Sport to be used post competition (see appendix 4). For example, a challenge item "*I expect I will achieve success rather than experience failure*" was reworded to "*I expected that I would achieve success rather than experience failure*". A threat item such as "*I feel that this task is a threat*" became "*I feel like this task was a threat*". Concurrent validity of the CAT-Sport with existing psychometric measures of excitement and anxiety, identified significant associations between both measures, supports the validity of the CAT-sport as measure to assess challenge and threat states (Rossato et al., 2016).

Internal reliability of all questionnaires used in this thesis was assessed for internal consistency by calculating the Cronbach alpha coefficient. A value of .75 was used to identify internal stability (Bland & Altman, 1997). If this was not achieved, the questions that least reflected the measurement of the construct was removed to increase the reliability. The construct was excluded from the analysis if the removal of item(s) did not bring internal stability above an alpha coefficient of .75.

3.9 Data analysis

3.9.1 Movement execution

All the continuous and instantaneous variables derived from the kinematic analysis were averaged for a trial and condition. Before the averages were calculated movement execution variables were screened for outliers. Firstly, outliers were identified by calculating absolute z-scores from each variable within a trial of an individual participant according to the formula

$$z = \frac{X - Xm}{SD}$$

Where z is the z-score derived from the score of measure X, the mean score of measure X from the population (Xm) and the standard deviation from the population. Based on a normal distribution and a 95% confidence interval, outliers were identified when the absolute z-score was above 1.96 and highlighted as a potential outlier to be removed from the data set (e.g., excluded from calculation of the average in a block or condition). A further examination of the identified outliers was conducted by analysing z-scores within participants. As novice golfers were used as participants there was an expected variability between participants in movement execution. To accommodate for this, the identified z-score outlier was first compared to the z-scores of the other trials of the participant to identify whether the participant executed the task consistently differently from other participants. The data was not considered an outlier when the z-scores were comparable to other trials (below 1 standard deviation) of the participant. In addition, a repeated measures research design (as in chapter 5) reduces the influence of these type of outliers. Identified extreme outliers (>3SD) were mainly due to missing data arising from the collection of positional data from the markers (i.e., marker dropping out) and resulted in removal of all movement variables from individual putt. With the combined screening of outliers, both within and between participants, there were less than 1% of trials removed.

3.9.2 Visual Search behaviour

To assess the reliability of the mapping of POR on an AOI a random selection of trials (10% of the total trials) were coded by two researchers to assess for agreement in coding POR on an AOI. The inter-rater reliability between the two coders was assessed with a single measure, absolute agreement model of intraclass correlation coefficients (ICC, Koo & Li, 2016). ICC values between 0.75 and 0.9 were accepted as good reliability and values greater than 0.9 as excellent reliability (Koo & Li, 2016). All variables derived from the eye tracking analysis were calculated as the average for five condition-block trials (e.g., the five attempts in one type of blocks in a pressure condition).

3.9.3 Alpha-Amylase and cortisol

All saliva samples were analysed in duplicate for cortisol and singular for alpha-amylase. Cortisol samples were included in the analysis when the coefficient of variation (CV) between the duplicate measurements was below 10% (100% of the samples). The average concentration of the two duplicate analyses was calculated and used for further analysis.

Cortisol concentration was transformed from $\mu g \cdot dL^{-1}$ to $nmol \cdot l^{-1}$. sAA was corrected for flow rate and expressed in $U \cdot min^{-1}$. In short, saliva samples were weighed and based on a saliva density of 1.0 $g \cdot ml^{-1}$ and the exact sample collection time, an expression of sAA in $U \cdot min^{-1}$ was derived. An inherent problem with cortisol and sAA reactivity is the great inter-individual variation between participants at baseline, in addition to changes around a stress task. This often results in a positive skew and non-normal distribution. Whenever cortisol or sAA was not normally distributed a log10 transformation of cortisol and sAA concentration was used to normalise the data before the statistical analysis. Note that all cortisol and sAA data presented graphically in the experimental chapters contain the untransformed data.

3.9.4 Statistical analysis

Details of specific inferential statistics used in this thesis are presented in the experimental chapters.

Chapter 4: The influence of psychosocial stressors on the endocrine response in a laboratory controlled perceptual motor task

4.1 Introduction

Within a systematic review with meta-analysis, presented in experimental chapter 2, it was identified that athletes experience a significant anticipatory cortisol response before participating in real sport competitions. However, the examination of stress and anxiety on visual attention and performance execution are typically conducted in laboratory environments where a simulation of a social evaluative and competitive sport environment is created. The advantage of utilising a laboratory compared to outdoor or 'live' sporting situation is the level of control afforded to the study. To simulate such an environment, studies regularly adopt Baumeister and Showers' (1986) suggested methodological approaches including a combination of self-presentation and motivational stimuli such as financial incentives (Cooke et al., 2010; Hardy et al., 1996; Wilson et al., 2009), performance evaluation (Cooke et al., 2010; Hardy et al., 1996; Wilson et al., 2009) and/or an audience (Hasegawa et al., 2013; Mesagno et al., 2011). Although single stimuli are likely to influence motivation to complete the task, it is the combination of stimuli that will create an environment where participants will develop anxiety (Mesagno et al., 2011). Indeed, Mesagno et al. (2011) highlight that self-presentation pressure stimuli (e.g., audience and performance evaluation via video camera) individually and combined with performance contingent monetary incentives, increases cognitive and somatic anxiety more than merely motivational stimuli such as monetary incentives. Depending on the intensity of the experienced negative emotions, these will concurrently trigger a biological stress response, reflected in activation of the HPA-axis and SNS. The activation of these stress pathways can be assessed limited invasively with the salivary biomarkers cortisol and sAA respectively (Alix-Sy et al., 2008; Granger et al., 2007; Hellhammer et al., 2009; Lovallo & Thomas, 2000; Rohleder et al., 2004; Salvador, 2005). Although commonly assessed in real sport competitions (Salvador, 2005) and in the general psychology domain (Dickerson & Kemeny, 2004; Granger et al., 2007), there are currently no studies that have evaluated the activation of these stress pathways in a laboratory setting with the self-presentation and motivational stimuli used in the sport domain (Lautenbach & Laborde, 2016). This is surprising for two reasons. Firstly, these pressure manipulations are often used to examine the role of stress and anxiety on visual search behaviour and movement execution where there is evidence that particularly the hormone cortisol directly influences both attentional control as well as fine motor skills (Hatfield et al., 2013; Shields et al., 2015). Secondly, SNS and HPA-axis reactivity, assessed via sAA and cortisol, have poor correlations with measures of personality and retrospective analysis of experienced stress (Gaab et al., 2005) and weak associations with state measures of anxiety (Kudielka et al., 2009), highlighting the independence of the endocrine stress response from the emotional response.

Activation of the SNS and HPA-axis are linked to distinctive psychological determinants (Henry, 1992); challenge and effort are linked to SNS activation where lack of control, threat and an unpredictable outcome are more associated with HPA-axis activation (Dickerson & Kemeny, 2004; Hellhammer et al., 2009; Henry, 1992). The influence of acute psychological stressors in a laboratory settings on the cortisol response has been extensively examined in the psychological domain (Dickerson & Kemeny, 2004). A meta-analysis by Dickerson and Kemeny (2004) identified that cortisol levels significantly increase in social evaluative situations, specifically with the presence of an evaluative audience or with negative social comparisons. In contrast, social evaluation by video recording, noise exposure or motivational tasks, such as a mental arithmetic task, do not elicit a significant cortisol response. This is reflected in a study by Lautenbach, Laborde, Achtzehn and Raab (2014) where the investigation into the relationship between cortisol reactivity and tennis serve performance was predisposed due to the used mental arithmetic manipulation that did not significantly increase cortisol levels. The results of the meta-analysis by Dickerson and Kemeny (2004) identified that cortisol levels increase two fold, when a motivated task is completed under a social evaluative situation. Although Dickerson and Kemeny (2004) highlight the evaluative nature of the audience, they did not separate for the behaviour of the audience within their analysis. Whilst there is evidence that the mere presence of an audience, irrespective of their behaviour (unsupportive or supportive), increase cortisol levels (Taylor et al., 2010), the majority of studies highlight that both increased audience sizes and negative behaviour of an audience increases cortisol levels more than a supportive audience and smaller audience sizes (Dickerson, Mycek, & Zaldivar, 2008; van den Bosch et al., 2009; Wiemers, Schoofs, & Wolf, 2013). This suggests that with the inclusion of an audience, as a self-presentation pressure stimuli, a negative evaluative audience is more likely to influence cortisol levels than a neutral or positive audience.

Based on the evidence from the psychology domain it is expected that a combination of self-presentation stimuli and performance contingent monetary incentives activate both the SNS and the HPA-axis. However, a consistent finding is the great inter-individual reactivity of the endocrine response. Factors such as gender, genetic predisposition, physical fitness, habituation to stress and early life experiences are suggested to influence cortisol reactivity (Boyce & Ellis, 2005; Kudielka et al., 2009; Rimmele et al., 2007). For example, males tend to demonstrate greater cortisol reactivity in anticipation and reaction to participating in a psychosocial stress task (Engert et al., 2013; Kudielka & Kirschbaum, 2005). Similar gender differences in cortisol reactivity were also identified in athletes anticipating real sport competitions in chapter 2 (van Paridon, Timmis, Nevison, & Bristow, 2017). In contrast, men with high levels of physical fitness, demonstrated lower cortisol reactivity in a psychosocial stress task than men with low levels of physical fitness (Rimmele et al., 2007). Although some of these confounding variables can be controlled for in experimental studies (e.g., physical fitness, gender) it is not possible to control for all variables that influence the HPA-axis. Hence, differences in inter-individual reactivity are expected in studies assessing salivary cortisol in psychosocial stress manipulations. In addition, these inter-individual differences in HPA-axis activity could reflect a different interpretation of the social evaluative situation corresponding to the propositions of the BPSM; greater cortisol reactivity indicating a more threatening state. These inter-individual differences in stress reactivity offers opportunities to examine the influence of stress reactivity on predictor variables. To this extent, studies regularly rely on separating the participant population into groups based on a change in cortisol concentration over time (e.g., responders and non-responders, Miller, Plessow, Kirschbaum, & Stalder, 2013) to examine differences in for example functional brain connectivity (Quaedflieg et al., 2015), social decision making (Steinbeis, Engert, Linz, & Singer, 2015) and motor performance in musicians (Ioannou, Furuya, & Altenmüller, 2016). As stress-reactivity is suggested to be associated with sport performance (Casto & Edwards, 2016; Salvador, 2005) there is the need to evaluate whether the SNS and HPA-axis can be successfully activated in a laboratory setting, before the influence of stress on visual attention and motor performance is examined. The meta-analysis presented in chapter 2 showed that males experience a significant anticipatory cortisol response before participating in sport competition (d=1.01). The aim of the current study is to evaluate whether a pressure manipulation with self-presentation stimuli and performance contingent financial incentives creates an endocrine response similar to that experienced in real sport competitions and that identified in chapter 2.

4.2 Methods

Twenty eight male participants, age 23±6 yrs, with limited golf putting experience, completed golf putts under a high pressure condition. The experiment received institutional ethical approval and written informed consent was obtained from all participants. The tenets of the Declaration of Helsinki were observed.

4.2.1 Design and procedures

A correlational design was used in this study were all participants completed a golf putting task under a high pressure condition. Within the putting task participant were required to complete 20 golf putts from 3.5m towards a standard size hole with the equipment as outlined in the general method. Five saliva samples were collected with Salimetrics Oral Swabs (SOS) to assess both sAA and cortisol reactivity in anticipation and reaction to the high pressure golf putting task (see figure 4.1). A control saliva sample was collected on arrival in the laboratory before full disclosure of procedures. In addition, saliva samples were collected immediately before and after the putting task as well as at 20 and 40 minutes after completing the putting task.

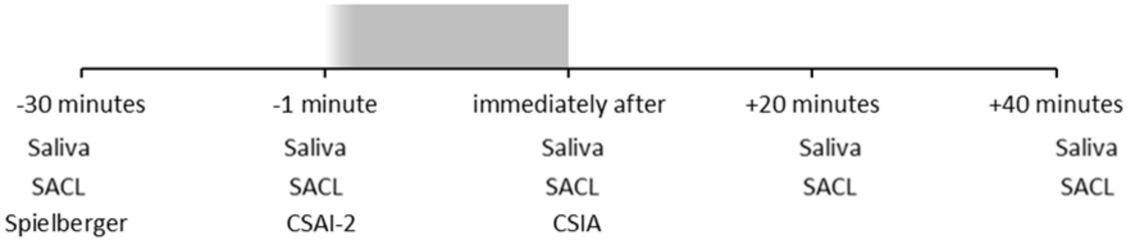

Figure 4.1 Timeline of the data collection procedures in relation to the golf putting task (grey area). Stress Arousal checklist (SACL), Spielberger trait anxiety inventory, Competitive State Anxiety Inventory-2 (CSAI-2) and Coping style Inventory for Athletes (CSIA).

4.2.2 Stress manipulation

The high stress manipulation, as outlined in the general methods, was used.

4.2.3 Measures

Cortisol and sAA were derived from saliva samples with the procedures as outlined in the general method. Concurrently with providing saliva samples participants completed the SACL (Mackay et al., 1978), where an acceptable Cronbach's alpha for the arousal and stress constructs were identified (.77 and .83 respectively).Trait anxiety was measured on arrival in the laboratory (-30 minutes before the golf putting task) with the 20 item Spielberger Trait anxiety inventory (Spielberger et al., 1970). Reported internal consistency range from 0.86 to 0.92 where an acceptable Cronbach's alpha of 0.91 was identified in the current study. State anxiety was assessed with the CSAI-2 immediately before the start of the golf putting task (-1 minute) (Jones & Swain, 1992; Martens et al., 1990). The CSAI-2 had an acceptable internal consistency varying from Cronbach alpha scores from .82 to .87 for the three constructs, comparable to values previously reported by Martens, Vealey and Burton (1990). The directional element had acceptable internal reliability scores varying from .75 to .82. Coping strategy was measured immediately after completing the golf putting trial, with the amended version of the Coping Style Inventory for Athletes (CSIA) and the Coping Style in Sport inventory (CSSI) (Anshel & Kaissidis, 1997; Anshel et al., 2009). The amended CSIA version in the current study had an acceptable internal consistency of .75, comparable to previous reported findings varying from 0.68 to 0.84 (Abedalhafiz et al., 2010; Anshel et al., 2009).

4.2.4 Data analysis

All analysis were conducted in SPSS for Windows, Version 20.0 (Armonk, NY: IBM Corp). Both cortisol and α-amylase levels were not normally distributed. A log transformation was applied to correct for a positive skew in cortisol and sAA. Participants were grouped into responders (n=14) and non-responders (n=14) based on a positive change in cortisol of 1.5 nmol/l (responder) or negative (non-responder) change in cortisol from baseline (-30 min) to the samples collected around the golf putting trial (Engert et al., 2013; Miller et al., 2013). Log transformed cortisol and α-amylase data and the stress and arousal constructs of the SACL, were analysed using a repeated measures ANOVA. The sampling collection points were used as the within subject factor and responders and non-responder as between subjects groups. Level of significance was set at $p<.05$. A Greenhouse-Geisser correction was applied when the assumptions of sphericity were violated. Simple contrasts were used to identify differences between the two groups and pairwise comparisons with Bonferroni correction for within group effects. Effect sizes for repeated measures analyses are reported as partial eta squared (η_p^2) and as Cohen's d for pairwise comparisons. The association between self-reported measures of anxiety, stress, coping and cortisol and α-amylase levels were assessed with one-tailed bivariate correlations and Pearson correlation coefficients. All figures of cortisol and α-amylase levels present the original, non-log transformed data.

4.3 Results

4.3.1 Self-reported measures of anxiety

The results of the CSAI-2 indicated that participants were moderately anxious before commencing the trial. Scores on cognitive anxiety (18.1 ± 5.4), somatic anxiety (15.1 ± 4.3) and self-confidence (22.9 ± 5.6) are comparable to reported in previous studies examining the effects of anxiety on motor skill performance (Chamberlain & Hale, 2007; Mullen et al., 2005)

4.3.2 Cortisol

No significant group main effect was found for cortisol between the responder and non-responder group ($F(1,26)=1.31$, $p=.26$, $\eta_p^2 =0.048$). A significant time main effect ($F(3.2,83.3)=14.12$, $p<.001$, $\eta_p^2=0.352$) and time by group interaction effect ($F(3.2,83.3)=17.16$, $p<.001$, $\eta_p^2=0.398$) supported the grouping of participants into cortisol responders and non-responders (see figure 4.2). Contrasts showed that cortisol for non-responders was significantly higher at baseline (-30 minutes) than for responders ($p=.042$, $\eta_p^2=0.15$). Immediately before the trial (-1 minute) responders had a significantly higher cortisol concentration than non-responders ($p=.047$, $\eta_p^2=0.143$). There was a trend for cortisol to be higher in the responders compared to the non-responders immediately after the trial ($p=.055$, $\eta_p^2=0.134$). No significant differences in cortisol between the groups were found at 20 and 40 minutes after the trial.

Responders had significantly higher cortisol levels immediately before the trial (-1 min) in comparison to 30 minutes before ($p=.005$, d=1.04) and 40 minutes after ($p=.001$, d=0.98). Cortisol levels immediately after the trial were significantly higher than 30 minutes before ($p=.004$, d=0.99) and 40 minutes after the trial ($p=.001$, d=0.92). The cortisol levels immediately after the test were significantly higher than 20 minutes after the trial ($p=.030$, d=0.32). The non-responders had a significantly higher cortisol at -30 minutes in comparison to the other four time points ($p<.001$, average d=0.73). No other significant differences were identified (see figure 4.2).

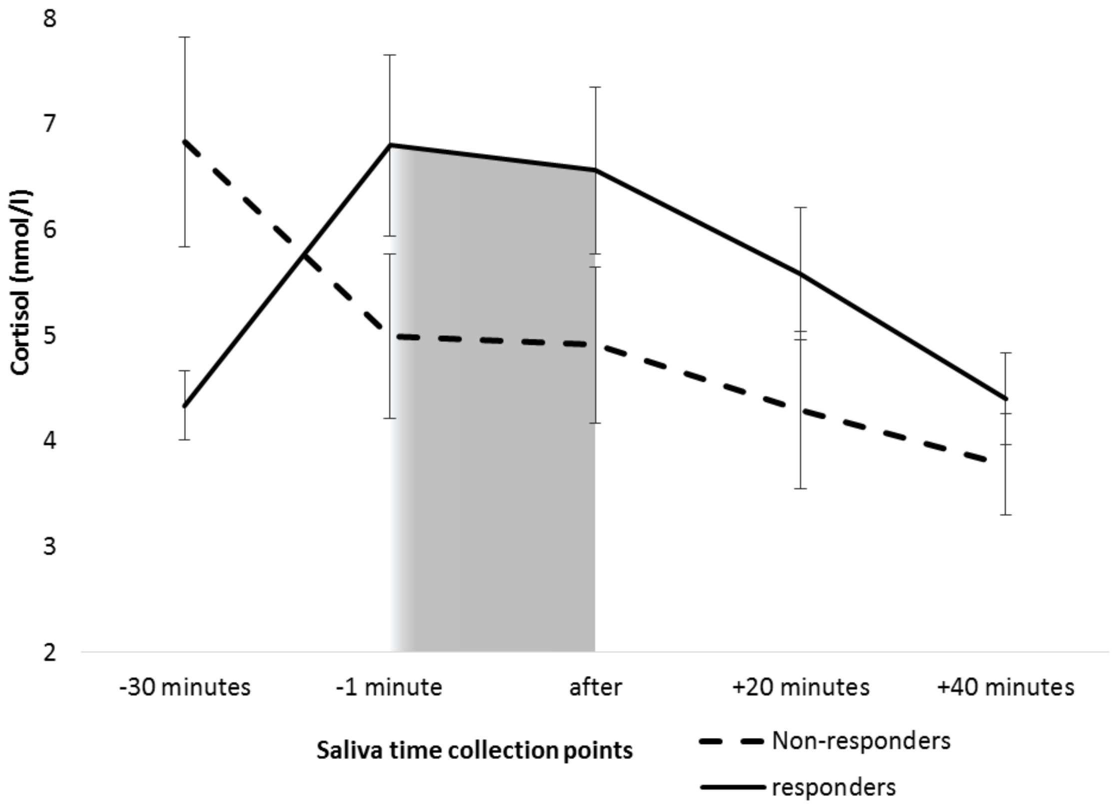

Figure 4.2 The cortisol concentration in saliva (nmol/l) at the 5 time collection points for responders and non-responders (M ± SE). Shaded area denotes period of golf putting task.

4.3.3 Salivary α-amylase

There was no significant main effect for sAA between the non-responder and responder group ($F(1,25)=0.27$, $p=.61$, $\eta_p^2=0.01$) There was a significant time main effect ($F(4,100)=3.77$, $p=.007$, $\eta_p^2=0.13$) where α-amylase immediately before the trial (-1 minute) was significantly higher than 30 minutes before ($p=.010$, $d=0.53$) and 20 minutes after ($p=.018$, $d=0.44$). No significant time by group interaction effect ($F(4,100)=0.19$, $p=.94$, $\eta_p^2=0.007$, see figure 4.3).

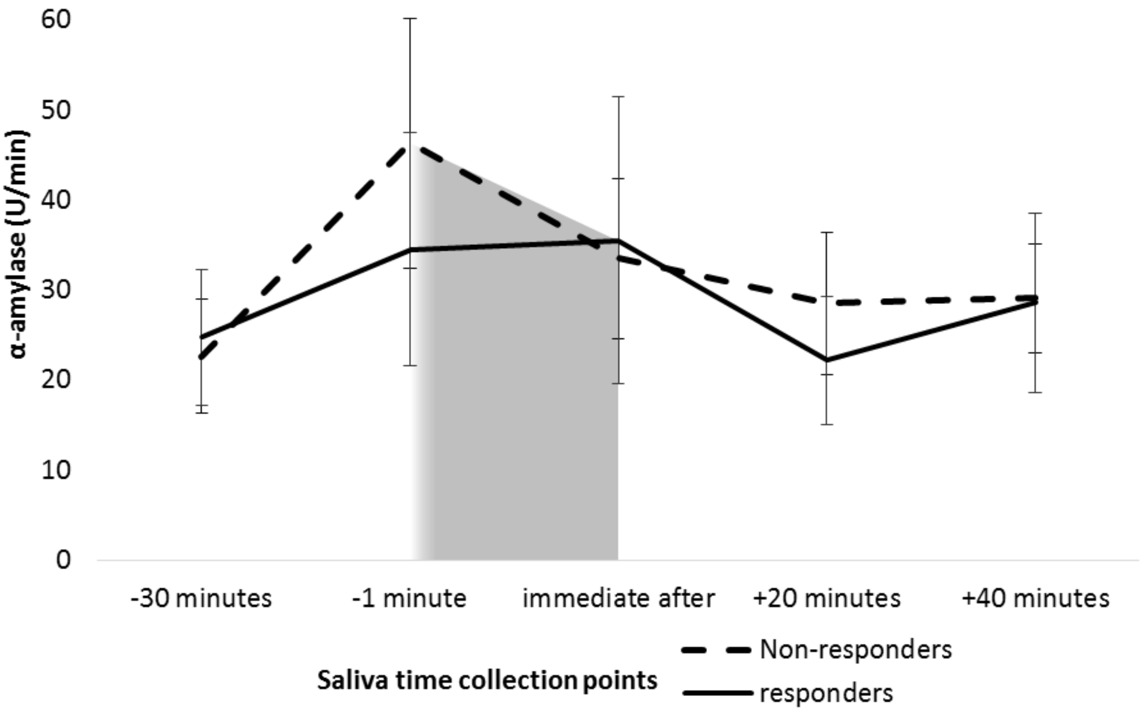

Figure 4.3 The α-amylase concentration in saliva (U/min) at the 5 time collection points for responders and non-responders (M ± SE). Shaded area denotes period of golf putting task.

4.3.4 Stress Arousal Checklist: stress

There was no significant group main effect for the stress construct of the SACL between the responder and non-responder group ($F(1, 25)=0.27$, $p=.61$, $\eta_p^2=0.011$). There was a significant time main effect for the stress construct of the SACL ($F(2.42, 60.47)=11.82$, $p<.001$, $\eta_p^2=0.32$) where stress immediately before the trial (-1 minute) was significantly higher than 30 minutes before ($p=.010$), 20 minutes after ($p=.001$) and 40 minutes after ($p<.001$). Stress immediately after the trial was significantly higher than 20 ($p=.008$) and 40 minutes after the trial ($p=.002$). No significant time by group interaction effect was identified ($F(2.42, 60.47)=.15$, $p=0.90$, $\eta_p^2=0.00$). See figure 4.4

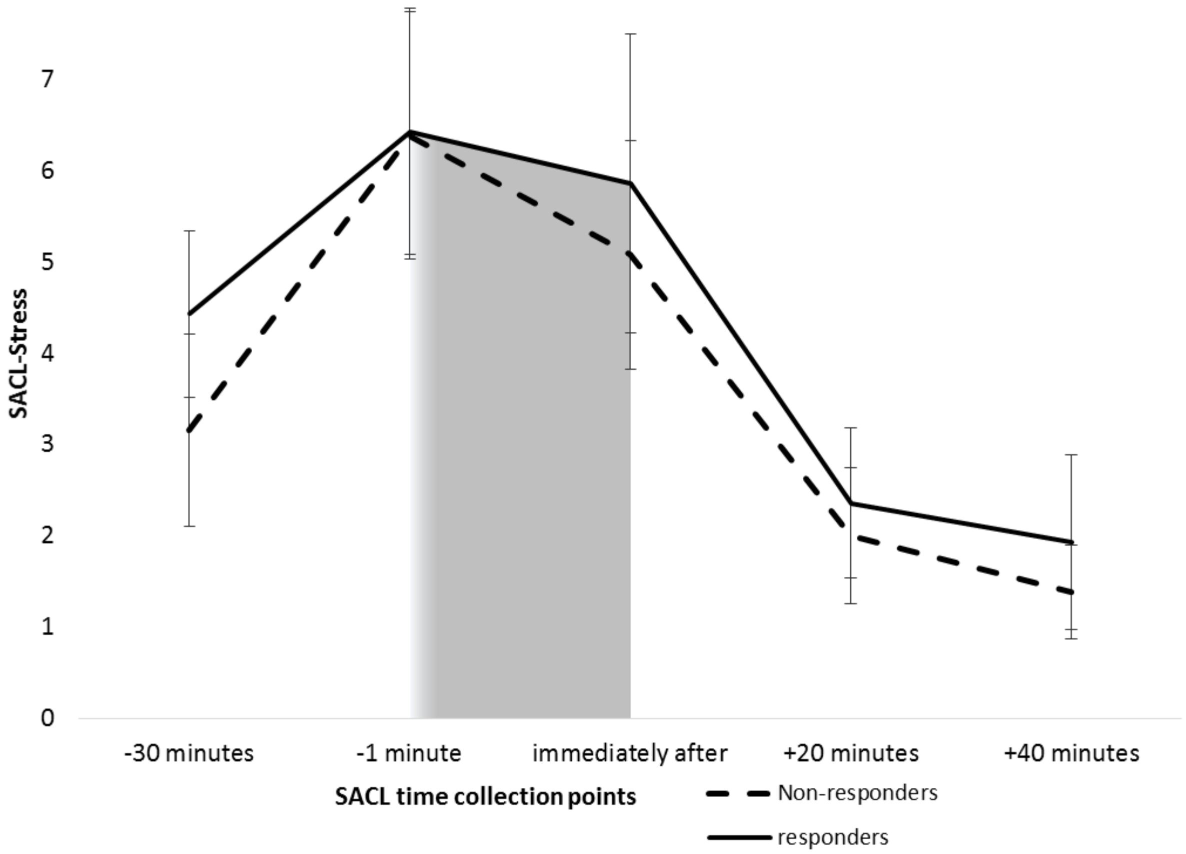

Figure 4.4 The SACL stress levels at the 5 time collection points for responders and non-responders (M ± SE). Shaded area denotes period of golf putting task.

4.3.5 Stress Arousal Checklist: Arousal

There was no significant group main effect for the arousal construct of the SACL between the responder and non-responder group ($F(1,25)=0.72$, $p=.41$, $\eta_p^2=0.03$). There was a significant time main effect for the arousal construct of the SACL ($F(2.70, 67.15)=4.81$, $p=.006$, $\eta_p^2=0.16$) where arousal immediately after the trial was significantly higher than 40 minutes after ($p=.038$). No significant time by group interaction effect was identified for the arousal construct of the SACL ($F(2.70, 67.15)=1.42$, $p=.23$, $\eta_p^2 = 0.05$). See figure 4.5

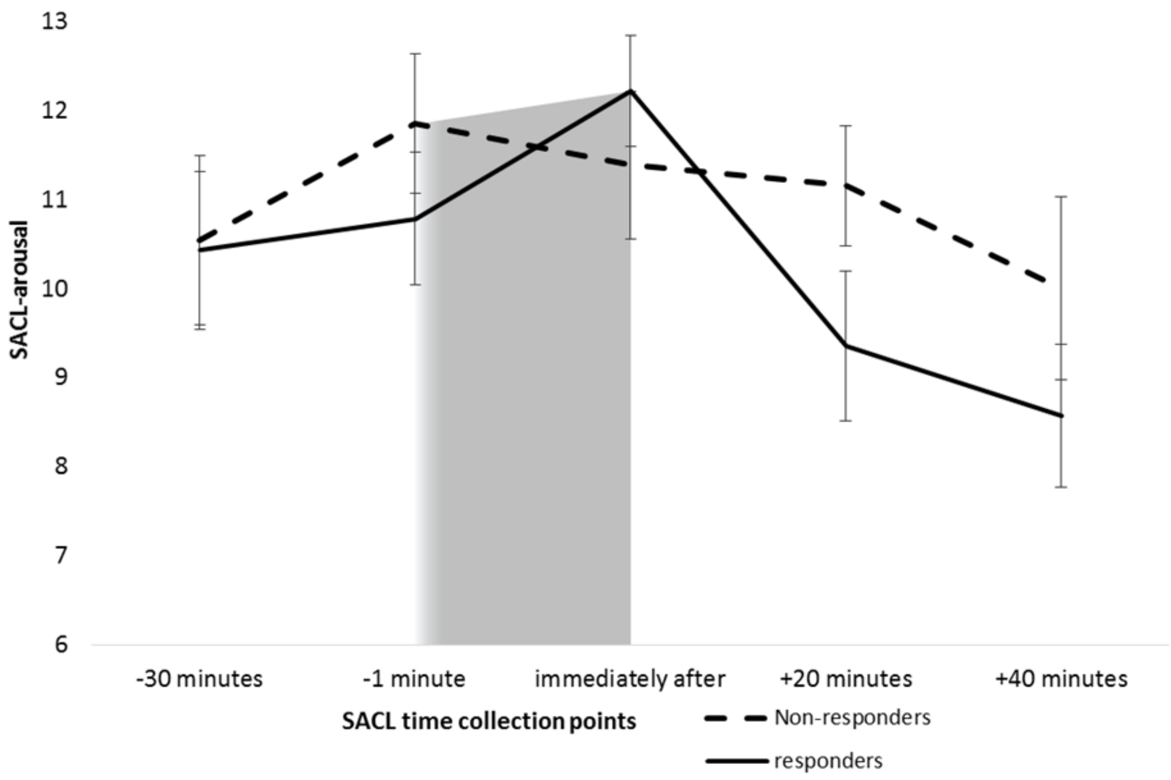

Figure 4.5 The SACL-arousal levels at the 5 time collection points for responders and non-responders (M ± SE). Shaded area denotes period of golf putting task

4.3.6 Anxiety and endocrine response association

No significant associations were identified between the change in cortisol and sAA from -30 minutes to immediately before the trial and constructs of the CSAI-2 (p>.05). There were no significant associations between the cortisol concentration and the SACL stress construct at the 5 time collection points (p>.05, r -.01 to .25) and cortisol and the arousal construct of the SACL (p>.05, r -.27 to -.02). In addition, there was no significant association between α-amylase and the SACL stress construct (p>.05, r -.11 to .06). The arousal construct of the SACL had a significant association with α-amylase at 20 minutes after (p<.05, r=.34) and 40 minutes after (p<.01, r=.49) but not at other time points (p>.05, r=-.17 to .15).

4.3.7 Anxiety and endocrine associations in responders and non-responders

Within the group of responders there was a significant association between the increase in cortisol from -30 minutes before the trial to around the trial and the interpretation of the somatic anxiety symptoms (r=-.61, p<.01). The increase in sAA from immediately before the trial to 30 minutes before the trial was significantly associated with trait anxiety (r=-.50, $p<.05$). Within non-responders these differences were not identified. No other associations were identified ($p>.05$).

4.3.8 Associations between cortisol and sAA

No significant associations were identified between cortisol concentration and sAA concentration at the time collection points for the total populations ($p>.05$) and within responders and non-responders groups ($p>.05$).

4.3.9 Associations between self-reported measures

The association between self-reported measures indicated that the stress construct of the SACL immediately before the trial significantly and positively correlated with trait anxiety and both the cognitive and somatic components of the CSAI-2. In addition, the stress construct of the SACL was significantly and negatively associated with the self-confidence construct and the cognitive and somatic directional component of the CSAI-2 (see table 4.1).

Table 4.1 Correlations, means and standard deviations of self-reported measures.

Measure	1	2	3	4	5	6	7	8	9	10
1. S-TA	--									
2. CSAI-2 Cog	.55**	--								
3. CSAI-2 Som	.32	.51**	--							
4. CSAI-2 CogDir	-.21	-.20	-.24	--						
5. CSAI-2 SomDir	-.07	-.24	-.29	.75**	--					
6. CSAI-2 Conf	-.45**	-.33*	-.68***	.47**	.22	--				
7. SACL ST (pre)	.51**	.65***	.80***	-.36*	-.35*	-.77***	--			
8. SACL AR (pre)	-.17	-.25	-.21	-.21	.04	.09	-.12	--		
9. CSIA Avoid	.44*	-.07	-.02	.29	.37*	-.07	.06	-.02	--	
10. CSIA App	.30	.26	.30	-.29	-.32	-.56**	.47**	-09	.14	--
M	37.4	18.1	15.1	-0.44	-2.1	22.9	6.4	11.3	22.2	30.1
SD	4.2	5.4	4.3	6.4	5.8	5.6	4.9	2.8	4.8	6.9

Note. Pearson correlations, mean and standard deviations for self-reported measures (n = 27). S-TA = Spielberger Trait anxiety questionnaire, CSAI-2 = Competitive State Anxiety Questionnaire with Cog = Cognitive scale, Som = Somatic scale, CogDir = Cognitive directional, SomDir = Somatic directional, Conf = Self-confidence, SACL ST (pre) = Stress Arousal Checklist Stress construct pre-trial, SACL AR (pre) = Stress Arousal Checklist Arousal construct pre-trial, CSIA = Coping Scale Inventory Athletes, Avoid = Avoidance construct, App = Approach construct. * p<.05, ** p<.01, *** p<.001.

4.4 Discussion

The current study was designed to investigate the combined effects of self-presentation pressure stimuli, in the form of an audience, and performance contingent monetary incentives, on the endocrine response during an aiming task. It was identified that the anticipation of completing the golf putting task under pressure elicited a significant increase in sAA (58%, from 23.7±25.4 to 40.6±49.6 U/min, figure 4.3), reflecting activation of the SNS to the pressure manipulation. These absolute values are comparable to post pressure manipulation sAA concentration in studies using the Trier social stress test (TSST, (Rohleder, Wolf, Maldonado, & Kirschbaum, 2006)), in simulated sport competition (Mullen et al., 2016) and in real sport competition (Chiodo et al., 2011). However, the observed significant increase in sAA in anticipation to the task are not commonly found (Chiodo et al., 2011; Kivlighan & Granger, 2006). The collection of saliva immediately before the task (-1 min) allowed for the assessment of the expected rapid increase and peak in SNS activation. Studies not identifying this anticipatory sAA response (Chiodo et al., 2011; Kivlighan & Granger, 2006) collected saliva samples more than 10 minutes before the onset of the stress manipulation, and hence might have missed the rapid increase in SNS activation. In contrast to sAA, there was clear evidence of large inter-individual differences in cortisol reactivity. Half of the participants, categorised as responders, had a significant increase in cortisol from baseline (-30 minutes) to around the task (e.g., -1 minute and immediately after), reflecting HPA-axis reactivity (2.4 nmol/l, d=1.04, see figure 4.2). This increase in cortisol in the responder group is of similar magnitude to studies using psychosocial stress manipulation such as the TSST (Dickerson & Kemeny, 2004). In addition, this increase in cortisol in the responder group is comparable to the anticipatory cortisol response in males in real sport competition, d = 1.01, chapter 2, (van Paridon et al., 2017). Therefore, based on the magnitude of HPA-axis and SNS reactivity, the findings of the current study support the use of self-presentation and performance contingent monetary incentives in a laboratory environment, to create a pressure situation that is comparable to that identified in real sport competitions. However, this increase in cortisol was only identified in the responder group. The non-responders in this study were characterised by significantly higher cortisol on arrival in laboratory (-30 minutes) in comparison to consecutive time points after arrival (see figure 4.2). In addition, cortisol on arrival in the laboratory was significantly higher in the non-responder group than the responder group. This could indicate that the early perception of anticipation and participation in the task, interfered with the expected cortisol response associated with the stress manipulation (Engert et al., 2013). Hence it is recommended to collect baseline samples on a separate day or allow for sufficient time of habituation to the laboratory environment (Engert et al., 2013). Despite a significant increase in cortisol in the responder group, and an effect size similar to real sport competition, it was identified that the maximum values found in the current study (6.8 ± 3.2 nmol/l) are lower than normally reported in studies using the TSST and real sport competitions (Dickerson & Kemeny, 2004; Filaire, Alix, Ferrand, & Verger, 2009). The reason for lower levels of cortisol might be associated with the type of participants recruited in the study and the low baseline levels on arrival in the laboratory. All participants were recruited from a sport and exercise science student population and were familiar with the laboratory setting, sport participation and competition. Rimmele et al. (2007) identified that physically trained men demonstrate a tendency to have a lower HPA-axis response to the TSST in comparison to untrained men. An analysis of cortisol reactivity between participants who regularly play sport versus participants who did not play sport was conducted to verify the possible mediating effects of regular sport participation on the cortisol response. However, there was no significant difference ($p>.05$) in cortisol reactivity between these two groups of participants. In addition, potentially due to testing taking place in the afternoon, the baseline levels of cortisol (4.3 ± 1.2 nmol/l) are below the normal circadian variation in cortisol concentration (Hucklebridge et al., 1998).

Although perceived stress and arousal (SACL) significantly increased immediately before and after the stress manipulation in both responders and non-responder compared to other time points, no consistent significant associations were found between emotional responses (SACL/CSAI-2) and HPA-axis and SNS activity in the total population, or for responders and non-responders. Although self-reported assessment of emotional responses (e.g., anxiety) is common in the sport domain, the weak association between cortisol, sAA and self-reported measures, highlights the important distinction between the experienced emotions and endocrine response (Engert et al., 2013; Mullen et al., 2016). In addition, the weak associations between cortisol and sAA provides further support for the independence of reactivity of the SNS and HPA-axis stress pathways in the sport environment (Engert et al., 2013; Nater et al., 2005; van Stegeren et al., 2008).

4.5 Conclusion

The HPA-axis and the SNS are activated in anticipation and reaction to completing a golf putting task in a laboratory environment with self-presentation stimuli and performance contingent monetary incentives. The significant increase and low variation in SNS activity highlights that participant were engaged with the social evaluative golf task. However, inter-individual differences in HPA-axis reactivity (i.e., cortisol) suggest that participants experienced the stress manipulation differently. These inter-individual differences in HPA-axis activity are likely to reflect that participants with greater HPA-axis activity experienced a higher threatened stated in comparison to the participants with lower cortisol reactivity. Although it was identified that self-reported stress significantly increased around the golf putting task, it is of particular interest that the endocrine response and the emotional response showed non-significant associations, suggesting that endocrine reactivity is distinct from the experienced emotions during the pressure manipulation. The independency of the endocrine and emotional response warrants different research designs to examine the effects of anxiety and the endocrine response on visual attention and performance execution in perceptual-motor skills. To examine the suggested negative effects of anxiety on visual attention and performance execution (Janelle, 2002; Vine et al., 2016; Wilson, 2008) a repeated measures design was adopted in chapter 5. Here, visual search behaviour and performance execution in the high pressure condition, a condition characterised by an increase in SNS activity and HPA-axis activity, was compared to a low pressure condition, with the aim of examining the effects of anxiety on the aforementioned variables. The inter-individual differences in cortisol reactivity identified in the current study, reflecting a more threatened stated according to the BPSM (Blascovich & Mendes, 2000; Dienstbier, 1989), with the suggested direct effects of cortisol on motor control (Hatfield et al., 2013) and the inhibition function (Shields et al., 2015), warrants the use of an exploratory research design in chapter 6. Here the inter-individual differences in endocrine reactivity and the effect of these on visual attention and performance execution were examined.

Chapter 5: Golf putting under pressure: examining performance and attentional control to task-relevant and irrelevant stimuli.

5.1 Introduction

The performance and successful execution of a perceptual motor-skill relies on the use of visual information from the environment to prepare for, update and monitor the execution of the skill (M. F. Land, 2009). Being selective in the direction of overt visual attention allows athletes to attend to relevant information and ignore task-irrelevant information within the execution of these skills. However, evidence from the cognitive psychology domain (Eysenck & Calvo, 1992; Eysenck et al., 2007) and sport science domains (Beilock & Gray, 2007; Janelle, 2002; Wilson, 2008) suggest that anxiety affects both the efficiency as well as the direction (e.g., to task-relevant or irrelevant sources of information) of visual attention. The results of chapter 4 identified that the combination of self-presentation stimuli and performance contingent monetary incentives creates a stress manipulation that is characterised by high task engagement, reflected in SNS activation, whilst increasing general stress and anxiety, leading to distinct changes in cortisol. The effects of heightened levels of anxiety on visual attention forms the foundations of attentional control theory (Eysenck et al., 2007). ACT advocates that anxious individuals have a reduced capacity to inhibit task-irrelevant stimuli, have longer response latencies disengaging from these stimuli and interpret these stimuli as more threatening (Derakshan et al., 2009; Eysenck & Derakshan, 2011). The development of ACT in the cognitive psychology domain predominantly compares high trait anxious individuals to low trait anxious individuals. In contrast, the examination of the role of ACT in the execution of goal-directed movement in the sport domain, tend to adopt a repeated measures design, where participants are exposed to a low and high pressure manipulation (Causer et al., 2011; Wilson et al., 2009; Wilson et al., 2009). However, studies have predominantly examined whether anxiety affects visual attention towards task-relevant information. For example, within a golf putting experiment, Vine, Lee, Moore and Wilson (2013) identified that the length of the QE was significantly shorter in missed compared to holed putts under a high pressure condition. Similarly, Causer et al. (2011) identified that the QE period was significantly shorter in shooting task under high anxiety conditions. Hence, studies particularly examine the role of anxiety on the goal-directed attentional system and postulate that these changes are due to a stronger influence of the stimulus-driven attentional system by means of attending to task-irrelevant external stimuli or internal worrying thoughts. Indeed, Wilson et al. (2009) did find support for this prediction. Within a penalty kick scenario, Wilson et al. (2009) identified that overt visual attention towards the goal keeper was increased under anxiety conditions, where overt visual attention towards task-relevant information (goal and ball) was not affected. Although the goal keeper can be considered a threatening stimulus, this stimulus is also highly task-relevant, hence suggesting that the increase in visual attention towards the goal keeper is the result of a reduction in pre-potent response inhibition, as evidenced by an increased tendency to look at the goal keeper (Friedman & Miyake, 2004). The effects of anxiety on the inhibition function can be assessed more purely when neutral or task-irrelevant stimuli are used. These stimuli can examine the role of anxiety on resistance to distractor interference (Friedman & Miyake, 2004). In the current study, the effects of anxiety on resistance to distractor interference was examined by means of positioning task-irrelevant stimuli, in the form of physical blocks, in close proximity to the ideal golf putting line. These blocks influence the task constraints of the putting task such that different size gaps were created on the putting line. A more difficult task, a small gap created by large blocks, compared to a large gap, created by small blocks, allowed for the examination of visual attention towards task-relevant (e.g., ball and hole) and irrelevant information as a function of task complexity and anxiety.

In addition to changes in the direction and dispersion of overt visual attention under conditions of high anxiety, efficiency of visual search behaviour also decreases (Janelle, 2002). Attentional narrowing under anxiety conditions (Easterbrook, 1959) results in an increase in the number of fixations to gather a similar amount of information from the visual field, consequently reducing efficiency of visual search behaviour (Janelle, Singer, & Williams, 1999; Williams et al., 2001; Wilson et al., 2006). This change in efficiency of visual search behaviour is adopted as measure of task efficiency in the examination of the role of ACT in sport performance (Wilson, 2008).

There is extensive support for the idea of changes in visual search behaviour under high pressure conditions; anxious participants have higher rates of visual scanning behaviour and experience problems with maintaining an attentional focus on task-relevant information (Janelle, 2002; Wilson, 2008). Importantly, research has not examined the influence of anxiety on selective visual attention to both task-relevant and irrelevant stimuli. Although studies commonly reported that under anxiety conditions participants attend more towards task-irrelevant stimuli, these stimuli are often not specified. Therefore, by including physical, and possible distracting blocks in the current study, it was possible to examine visual search behaviour to both task-relevant stimuli and task-irrelevant stimuli under different (high and low) pressure conditions.

5.1.1 Anxiety Effects on Movement Execution and Outcome in Golf putting

Despite the expected negative effects of anxiety on movement execution (Beilock & Gray, 2007), resulting in possible changes in performance outcome, results are often contradictory within or between studies. In novice golfers, Cooke, Kavussanu, McIntyre, & Ring (2010) found that increased anxiety negatively affected performance outcome (number of balls holed) whilst both accuracy in the end ball location or variability of movement execution were not affected. Tanaka and Sekiya (2010) identified kinematic changes in the execution of the putt under high pressure, however, this did not affect the outcome, accuracy and consistency of the end ball location. Mullen and Hardy (2000) found no significant differences in performance outcome, accuracy and movement execution when high and low pressure conditions were compared in low ability golfers. Contrasting results can be attributed to the selection of performance indicators determining ball velocity and direction as well as variation in the level of participants' ability and pressure manipulation protocols used. Changes in performance accuracy are pre-determined by impact velocity and club head angle at impact (Delay et al., 1997; Karlsen et al., 2008). However, studies predominantly examine variability in movement execution (Cooke et al., 2010; Mullen & Hardy, 2000; Tanaka & Sekiya, 2010) or impact velocity (Mullen & Hardy, 2000) but do not examine this in relation to impact angle. The effects of ability level on golf putting performance under anxiety were examined by Mullen and Hardy (2000). They identified significant differences in the effects of pressure on movement execution and accuracy between two groups of different ability golfers exposed to the same pressure manipulation; the performance of lower ability golfers was not affected by the pressure manipulation, where higher ability golfers improved performance under high anxiety conditions. Whereas Mesagno, Harvey and Janelle (2011) identified that different combinations of commonly used pressure manipulations in the sport science domain (e.g., audience, monetary rewards, performance evaluation) creates distinct levels of emotional responses, where the highest anxiety responses are reported when self-presentation and performance contingent monetary rewards are combined (see chapter 4). Therefore, there is great variety in the suggested effects of pressure on performance in golf putting tasks where changes in performance execution often do not lead to changes in accuracy or outcome in a golf putting task. In addition, although some of these experiments examined underlying models of performance breakdown under high pressure (e.g., conscious processing hypothesis) none examined the possible mediating effects of visual attention on the execution of a golf putting task under pressure.

5.1.2 Aims

In line with the suggestion of Nieuwenhuys and Oudejans (2012) to examine the effects of anxiety on goal-directed actions (e.g., a golf putt) at the levels of visual attention and behaviour the aim of the current study was to examine the effects of anxiety on visual attention, performance execution and performance outcome in a golf putting task. Specifically, in the current study participants (i.e., novice golfers) were required to putt balls to a hole in a low pressure and high pressure conditions and under various irrelevant stimuli conditions (i.e., small, medium, large and no blocks). Furthermore, process (i.e., visual search behaviour and movement execution) and outcome (i.e., distance from hole and number of holes made) variables were measured and analysed.

Based on previous research on the effects of anxiety on perceptual-motor skill performance it was predicted that under high pressure conditions, in contrast to a low pressure condition (1) more frequent and longer duration gazes would be made to task-irrelevant stimuli in the environment; based on ACT (Eysenck & Derakshan, 2011) at the expense of a reduction in visual search behaviour towards task-relevant information (2) this reduction in efficiency in visual search behaviour will increase variation in movement execution and negatively affect performance outcome.

5.2 Methods

5.2.1 Participants

Thirteen male participants (M = 20.0 years, SD = 3.5) from a student population volunteered to participate in the study. All participants were right handed, had normal or corrected vision and were considered novice golfers with no golf or golf putting experience. The tenants of the Declaration of Helsinki were observed and the experiment received institutional ethical approval. The participants provided written informed consent before participation.

5.2.2 Design

A blocked randomised within-subject design was used. Participants putted golf balls towards a standardized hole under two pressure conditions. A control condition, without pressure manipulation (e.g., low pressure condition) and a high pressure condition. The completion of both conditions was randomised and separated by at least 4 days to minimise learning effects. The indoor putting mat and equipment as outlined in the general method was used. Within each pressure condition participants completed 4 sets of 5 putts in a randomised order. Three sets of putts had blocks on the putting green and one set had no blocks on the green. Pairs of white blocks of 10, 20 or 30cm width and 7cm height were positioned on both sides of the putting green, halfway (1.75 m) from the hole and acted as a source of task-irrelevant information (see figure 5.1). The blocks created a gap of 55cm, 35cm or 15cm width and are referred to as the large, medium or small gap condition respectively. In addition there was a no block condition (control condition) where no blocks were placed on the green.

Figure 5.1 Example of the small gap condition. This condition was created by positioning the 30cm blocks (e.g., large) on the putting green, creating a gap of 15cm width.

5.2.3 Self-reported measures

State anxiety: State anxiety was assessed with the modified Competitive State Anxiety Inventory-2 (CSAI-2: (Martens et al., 1990). The CSAI-2 had an acceptable internal consistency with Cronbach alpha scores from .79 to .90 for the three constructs, comparable to values previously reported by Martens, Vealey, & Burton (1990). The directional element had acceptable internal reliability scores varying from .75 to .88, in the range reported previously (Jones & Uphill, 2004).

Coping: Coping strategy was measured with an amended version of the Coping Style in Sport inventory (Anshel et al., 2009). An acceptable average internal consistency of .77 was found for the CSSI, comparable to the 0.68 to 0.84 Cronbach alpha scores previously reported (Abedalhafiz et al., 2010; Anshel et al., 2009).

5.2.4 Performance Outcome

The number of putts holed and frequency of hitting the blocks were recorded.

Performance accuracy was expressed as the mean radial error, as outlined in the general method. A holed putt received a score of 0 cm. When putts were long and were off the green the distance from the hole at the instance of leaving the green was used. When a putt did not pass the blocks, the score of the most inaccurate putt in the trial was used. Putts deflected by the blocks or hole were excluded from the analysis. Therefore, a low performance score indicates an end location closer to the hole (i.e., more accurate performance). Performance consistency in the end location of the ball in each condition by block trial was expressed as the bivariate variable error (BVE) as outlined in the general method.

5.2.5 Movement execution

The club head movement during the putting stroke was assessed with a three-dimensional motion analysis system (Codamotion, Charnwood Dynamics Ltd, Leicestershire, UK) and collected and processed as outlined in the general method.

5.2.6 Visual Attention

To assess visual search behaviour all participants wore a SMI mobile eye gaze registration system (IviewETG, SensoMotoric instruments Inc, Teltow; Germany, Ver. 1.0). The data collection and analysis were completed according to the procedures outlined in the general method. A random selection of trials (10%) was coded by two researchers. An excellent average intraclass correlation coefficient of 0.95 was observed for the combination of trial time (0.98, CI: 0.96-0.99) and the frame-by-frame mapping of the areas of interest ball (0.97, CI: 0.93-0.98) and hole (0.95, CI: 0.78-0.98).

5.2.7 Procedure

Participants completed the golf putting in both a high pressure and low pressure condition (as outlined in the general method) and reported to the laboratory to complete the golf putting task on an individual basis. Participants were briefed on the aims of the research, the equipment to be used and were randomly assigned to one of the pressure conditions. Before commencing the testing the participants were given a demonstration on the putting technique and grip. Participants were equipped with the eye tracker and completed 20 familiarisation practice putts without blocks on the green. Following the practice putts the participants were further informed about the pressure condition. Under the high pressure condition participants were informed about the prize money, the score board, video camera and the audience, before being seated to complete the CSAI-2. In the low pressure condition participants were asked to perform at their best, they were informed that their putting performance would be recorded and would be used to assess golf putting ability in comparison to other participants and to gather a baseline score of visual search behaviour and movement execution. After calibration of the eye tracking glasses the participants completed the 4 sets of 5 putts. Following completion of the trial the eye tracking glasses were removed and participants completed the CSSI. Participants then came to the laboratory 4-7 days later to complete the task under the second pressure manipulation condition. Each session lasted approximately 30 minutes. Short breaks were provided between block conditions to allow the setup of the blocks and to allow the participant to take a break if needed.

5.2.8 Statistical Analysis

The kinematic data of one participant had to be excluded from the analysis due to faulty equipment. Therefore the performance execution analysis included 12 participants, all other analysis were based on 13 participants. All analysis were conducted in SPSS for Windows, Version 20.0 (Armonk, NY: IBM Corp). Psychometric measures were analysed with a Wilcoxon signed ranks test. To ascertain whether learning effects affected performance outcome, analysis was conducted on the repetition effect between the performance (i.e., radial error) off the first putt, the 20th putt and the last putt completed. There was no significant effect of repetition on putting performance ($p > .05$). Performance execution, performance outcome and gaze behaviour variables were analysed with 2 x 4 repeated measures ANOVAs (pressure condition x gap size). Significant effects were further analysed with paired sample t-tests. To reduce the risk of a Type-I error a Bonferroni correction was applied to adjust the significance values.

Mediation analysis was used to test whether any psychological, kinematic or visual search behaviour variables mediated the effect of pressure manipulation on performance. Mediation from these variables were examined when the criteria that 1) the pressure manipulation had a significant effect on performance and 2) potential mediator variables were significantly different between the pressure conditions, were met. (Baron & Kenny, 1986). The low pressure/high pressure condition was used as independent variable (coded as 0 and 1) and mean radial error as dependent variable. Mediation analysis was done with the process custom dialog box for SPSS developed by Hayes (2013). The alpha level of all analysis was set at 0.05. Effect sizes for multiple comparisons are expressed as eta squared (η_p^2).

5.3 Results

5.3.1 Manipulation check

Compared to the low pressure condition, both cognitive and somatic anxiety were significantly greater in the high pressure condition (Cognitive: z=-2.3, *p*=.020; Somatic z=-2.1, *p*=.037). The facilitative or debilitative effects of anxiety from the directional scale of the CSAI-2 in both cognitive and somatic anxiety was not significantly different between the high and low pressure conditions (Cognitive: z=-1.41, *p*=.16; Somatic: z=-1.26, *p*=.21). There was a significant increase in the use of avoidance coping in the high compared to the low pressure condition (z=-1.97, *p*=.048). No significant difference was found in approach coping between the low and high pressure condition (z=-0.079, *p*=.94). The anxiety and coping results are presented in table 5.1.

Table 5.1 Mean (M) and standard deviation (SD) of anxiety and coping in low and high pressure condition

	Low pressure		High pressure	
	M	SD	M	SD
Cognitive anxiety (9-27)	14.7*	3.3	17.3	4.8
Somatic anxiety (9-27)	12.3*	2.6	14.9	4.2
Cognitive interpretation (-27-27)	1.69	4.88	-1.46	7.66
Somatic interpretation (-27-27)	5.0	7.37	-0.31	7.88
Avoidance coping (1-5)	2.46*	0.40	2.65	0.36
Approach coping (1-5)	2.63	0.64	2.66	0.83

Note. Significantly different from high pressure condition, * $p < .05$

5.3.2 Performance Outcome

There was no significant difference between the number of putts holed (p=.10) and number of times the blocks were hit (p=.85) in the low versus the high pressure condition. The effect of the different gap sizes and pressure x gap size interactions were not calculated due to the small number of balls that were successfully putted (i.e., holed) or hit the blocks.

The end location of the ball was significantly closer to the hole ($F(1,12)=8.17$, p=.014, $\eta_p^2=0.41$) in the high pressure (42.0 ± 19.8 cm) compared to the low pressure condition (51.4 ± 22.1 cm) (see figure 5.2). No significant effects for gap size (p=.17) or pressure condition x gap size interaction (p=.44) were found.

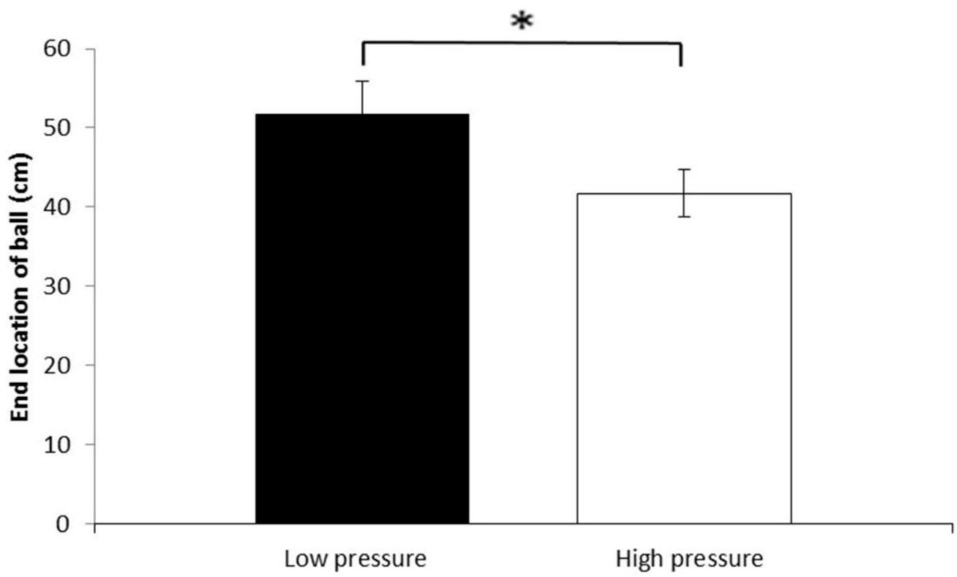

Figure 5.2 End location of the ball (in cm) relative to hole under low (black) and high pressure (white) condition (M ± SE). * *p* <. 05. 0 cm represents a successful putt.

The BVE of the end location of the ball was not significantly different between the high and low pressure condition (p = .72). The creation of different size gaps had a significant effect on the BVE of the end location of the ball ($F(3,36)=3.53$, $p=.024$, $\eta_p^2=0.23$). Post hoc analysis revealed that the BVE of the end location was greater with the small gap compared to the control condition ($p=0.001$). There was no pressure condition x gap size interaction effect in the BVE ($p=.41$). See table 5.2.

Table 5.2 Mean (M) and standard deviation (SD) of performance in low and high pressure condition

	Low pressure		High pressure	
	M	SD	M	SD
Nr of putt holed (0-20)	2	2	4	2
Nr of times blocks hit (0-15)	1	1	1	1
Mean Radial error (cm)	51.4*	22.1	42.0	19.8
BVE (cm)	30.9	12.9	30.8	12.5

Note. Significantly different from high pressure condition, * *p* < .05

5.3.3 Movement Execution

Preparation time: The time to complete the putt (from aligning the club head with the ball, preparing the shot, to striking the ball) was significantly shorter ($F(1,12)=4.88$, $p=.047$, $\eta_p^2=0.29$) in the high pressure condition (7.8 ± 2.6 s) compared to the low pressure condition (6.8 ± 2.3 s, see table 5.3). The different size gaps did not influence the completion time of the putt ($p=.12$) and there was no significant pressure condition x gap size interaction effect ($p = .06$).

Execution time: Execution time of the putting movement (combined backward-forward putter movement) was significantly shorter in the high pressure condition compared to the low pressure condition ($F(1,11)=8.46$, $p=.014$, $\eta_p^2=0.44$), with participants putting quicker in the high pressure condition. This reduction was predominantly due to a significantly shorter backswing time in the high compared to the low pressure condition ($F(1,11)=6.44$, $p=.028$, $\eta_p^2=0.37$). A trend with a moderate effect size was found for the downswing to be shorter in the high compared to the low pressure condition ($F(1,11)=4.58$, $p=.056$, $\eta_p^2=0.29$). The different size gaps did not influence the execution time variables and there were no significant interactions between pressure condition and gap sizes for these variables (all $p> .05$).

Club head kinematics

The club head kinematic variables were not significantly affected by the different size gaps that were created on the green ($p>.05$). In addition, no significant pressure condition by gap size interaction effects were found for the club head kinematic variables ($p>.05$). Therefore, only the effects of low and high pressure condition on club head kinematics are reported (see table 5.3).

Downswing

The backswing length was not significantly different between the low pressure and high pressure condition ($F(1,11)=0.005$, $p=.94$, $\eta_p^2=0.00$). However, the instantaneous velocity deviation in forward direction during the downswing was significantly greater ($F(1,11)=5.35$ $p=.041$, $\eta_p^2=0.33$) in the low pressure compared to the high pressure condition. The instantaneous velocity deviation in the lateral (y) direction during the downswing was not significantly different between the high and low pressure trials (p=.90).

Ball impact

The impact angle of the club head at ball impact was not significantly different between the high and low pressure condition (p=.38). However, the variable error of the club head angle at ball impact was significantly greater in the low pressure compared to the high pressure condition (F(1,11)=7.93, p=.017, η_p^2=0.42).

There were no significant differences in the velocity and variable error of the velocity of the club head at ball impact in the forward direction (p=.75 and .27 respectively) and the lateral direction (p=.67 and .47 respectively) between the low and high pressure condition. See table 5.3.

Table 5.3 Mean (M) and standard deviation (SD) of execution and club head kinematics in low and high pressure condition

	Low pressure		High pressure	
	M	SD	M	SD
Preparation time (s)	7.82*	2.56	6.81	2.32
Execution time (s)	0.90*	0.19	0.85	0.19
DS time (s)	0.29	0.058	0.28	0.052
BS time (s)	0.61*	0.14	0.57	0.14
BS length (cm)	20.89	6.31	20.74	4.78
SD X-velocity DS	0.48*	0.13	0.28	0.26
SD Y-velocity DS	0.032	0.014	0.033	0.015
X-axis impact velocity ($m.s^{-1}$)	1.41	0.38	1.46	0.29
Y-axis impact velocity ($m.s^{-1}$)	-0.019	0.050	-0.013	0.062
VE X-impact velocity ($m.s^{-1}$)	0.16	0.15	0.12	0.11
VE Y-impact velocity ($m.s^{-1}$)	0.050	0.044	0.044	0.025
Impact angle (°)	181.19	1.16	181.50	1.50
VE impact angle (°)	1.38*	0.81	1.09	0.56

Note. DS = downswing, BS = backswing, X = forward direction, Y = Perpendicular to putting line, VE = variable error, BVE = bivariate variable error, DS = downswing, BS = backswing. Significantly different from high pressure condition, * p < .05

5.3.4 Visual search behaviour

Scan rate

The total number of dwells per second was not significantly different between the high and low pressure condition ($F(1,12)=3.48$, $p=.087$, $\eta_p^2=0.23$). The different size gaps did not have a significant effect on scan rate ($F(3,36)=2.19$, $p=.11$, $\eta_p^2=0.15$) and there was no significant pressure condition by gap size interaction effect for scan rate ($F(3,36)=0.15$, $p=.93$, $\eta_p^2 = 0.012$).

Relative number of dwells

There was a trend with a moderate effect size for an increase in the relative number of dwells at the ball in the low pressure compared to the high pressure condition ($F(1,12) = 4.49$, $p=.056$, $\eta_p^2=0.27$). The relative number of dwells at the hole ($p=.43$), green ($p=.18$) and blocks ($p=.15$) were not significantly different between the low pressure and high pressure condition.

The influence of gap size on the relative number of dwells

The variation in gap size on the putting green had a significant effect on the relative number of dwells at the ball ($F(3,36)=8.38$, $p<.001$, $\eta_p^2=0.41$). Post hoc analysis revealed that there were significantly less dwells at the ball in the small gap condition compared to the medium ($p<.01$) and control condition ($p<.001$). No significant pressure condition x gap size interaction was identified for the relative number of dwells at the ball ($p=.92$).

In addition, gap size had a significant effect on the relative number of dwells at the hole $F(3,36)=8.21$ $p<.001$, $\eta_p^2=0.41$). There were significantly less dwells at the hole in the small gap condition in comparison to the large gap condition ($p< .001$) and the control condition ($p<.001$). A significant pressure condition x gap size interaction for the relative number of dwells at the hole ($F(3,36)=4.99$, $p<.01$, $\eta_p^2=0.29$) identified that there were significantly less dwells at the hole in the medium gap condition under low pressure compared to high pressure ($p<.05$).

The different size gaps that were created on the putting green had no significant effect on the relative number of dwells at the green ($p=.36$) and no significant pressure condition x gap size interaction effect was identified for the relative number of dwells at the green ($p = .71$)

Creating different size gaps on the green had a significant effect on the relative number of dwells at the blocks ($F(1.5,18.4)=38.19$, $p<.001$, $\eta_p^2=0.76$). Post hoc analysis identified that there were significantly more relative dwells at the blocks in the small gap condition in comparison to the medium and large gap condition (all $p<.001$). No pressure condition x gap size interaction effect was identified for the relative number of dwells at the blocks ($p>.05$). The control condition was excluded from the post hoc analysis as there were no blocks present on the putting green in this condition.

Relative Dwell times

The percentage of time looking at the blocks was significantly greater in the low pressure compared to the high pressure condition $F(1,12)=13.71$, $p=.003$, $\eta_p^2=0.53$). The percentage of time looking at the ball, hole and green were not significantly different between the high and low pressure condition (Ball, $F(1,12)=0.20$, $p=.67$, $\eta_p^2=0.016$; Hole, $F(1,12)=0.034$, $p=.86$, $\eta_p^2=0.003$; Green, $F(1,12)=0.19$, $p=.67$, $\eta_p^2=0.015$). The relative dwell times are presented in table 5.4.

The influence of gap size on the relative dwell times

The different size gaps created on the green had no significant effect on the relative dwell times at the AOIs Green, Ball and Hole (all $p>.05$). In addition, no significant pressure by gap interactions were found (all $p>.05$).

As expected, the variation of gap size on the putting green had a significant effect on the percentage of dwell time looking at the blocks ($F(1.22,14.63)=18.67$ $p<.001$. $\eta_p^2=0.61$), figure 5.3. Post hoc analysis revealed that the relative dwell times were significantly longer at the blocks in the small gap condition (5.2 ± 4.1 %) compared to the medium gap size (1.9 ± 1.6%, $p=.002$), and large gap size (1.3 ± 1.5%, $p=.001$). The control condition was excluded from the post hoc analysis. No pressure condition x gap size interaction was found for the relative time looking at the blocks ($p = .30$).

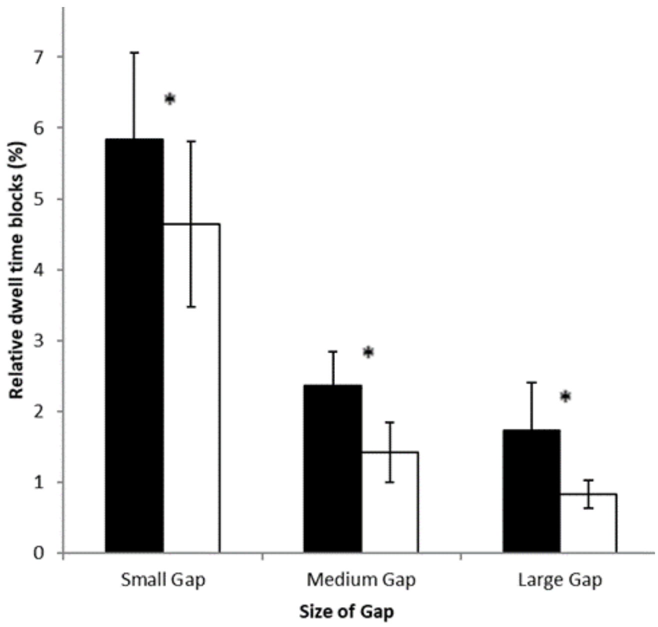

Figure 5.3 Relative dwell times at the blocks under low and high pressure condition (M ± SE). Low pressure: black bars, high pressure: white bars. * p <.05 for the high compared to low pressure condition in a gap comparison

Quiet eye period

The relative QE period was not significantly different between high and low pressure conditions (p=.93). No significant effect for gap size (p=.32) or pressure condition x gap size interactions were found for the relative QE period (p = .55).

Table 5.4 Mean (M) and standard deviation (SD) of visual search behaviour data in the low and high pressure conditions

	Low pressure		High pressure	
	M	SD	M	SD
Scan rate (nr.s^{-1})	1.96	0.69	2.35	0.90
%nr of dwells ball (%)	25.16	10.20	21.86	9.02
%nr of dwells hole (%)	10.14	6.23	11.28	4.55
%nr of dwells green (%)	39.50	9.14	41.47	5.64
%nr of dwells blocks (%)	7.21	6.70	5.99	6.08
%dwell time ball (%)	57.66	12.93	55.97	11.19
%dwell time hole (%)	18.26	13.61	18.77	12.12
%dwell time green (%)	15.56	10.60	16.68	8.94
%dwell time blocks (%)	2.48*	3.35	1.72	2.83
%QE (%)	28.23	11.69	27.87	14.34

Note. QE = Quiet eye. Significantly different from high pressure condition, * p < .05

5.3.5 Mediation analysis

The kinematic, psychological and gaze behaviour variables that were significantly different between the high and low pressure condition were included in the mediation analysis (Baron and Kenny, 1986). The indirect effects of the suggested mediator variables were derived via a 10.000 sample bootstrapping method with the SPSS Process dialog box (Hayes, 2013). Based on 95% confidence intervals a significant mediation was only found for the variable error of the impact angle. This suggests that the effects of the pressure condition on performance accuracy can be attributed to changes in variable error of the club head angle at impact. The results of the mediation analysis are presented in table 5.5.

Table 5.5 Mediation analysis results for variables that were significantly different between high and low pressure condition

	Effect	SE	LL 95% CI	UL 95% CI
Execution time	0.23	1.29	-1.27	4.57
Preparation time	-1.04	1.68	-0.48	0.06
VE putter movement time	-2.84	3.82	-14.05	2.14
BS time	0.093	1.25	-1.82	3.60
SD X-velocity DS	-1.75	3.36	-11.60	2.43
VE impact angle	-5.53	3.69	-15.37	-0.38*
Cognitive anxiety	-1.86	2.10	-8.66	0.62
Somatic anxiety	-2.75	2.02	-8.32	0.21
Avoidance Coping	1.03	2.24	-0.99	8.37
%Dwell times blocks	-2.42	2.96	-11.67	0.89

Note. SE = standard error, LL = lower limit, UL = upper limit, Significantly indirect effect between pressure condition and performance, * $p < .05$

5.4 Discussion

The main aim of the current study was to examine the effects of low and high pressure conditions on the performance, movement execution and visual search behaviour in a golf putting task. To examine the influence of anxiety on dividing visual attention between task-relevant and irrelevant information, the current study included task-irrelevant stimuli (i.e., blocks) in close proximity to the ideal putting line. The position of the blocks allows the examination of visual search behaviour to the task-relevant stimuli (i.e., hole and ball) and task-irrelevant stimuli under both high and low pressure conditions. The results indicate that the performance accuracy of novice participants increased under high pressure conditions. This improvement in performance can be attributed to a reduction in variation of the club head angle at impact as well as a change in visual search behaviour. Participants spent less time looking at the task-irrelevant stimuli (i.e., the blocks) in the high pressure condition suggesting a reduced influence of the stimulus-driven attentional system and more specifically, the inhibition function related to resistance to distractor interference under high pressure compared to low pressure conditions.

5.4.1 Manipulation check

The pressure manipulation resulted in a significant increase in self-reported cognitive and somatic state anxiety, where the high pressure condition created a similar level of state anxiety as in chapter 4. A comparison to norm values from real sport competitions suggests that the participants were experiencing below average levels of cognitive anxiety and somatic anxiety (Martens et al., 1990). However, the pressure manipulation created comparable state anxiety scores as other laboratory studies examining the effects of anxiety on motor skill performance (Chamberlain & Hale, 2007; Mullen et al., 2005) suggesting that participants were moderately anxious. Although participants reported to become more anxious in the high pressure condition this did not relate to a more negative interpretation of the anxiety. The combination of the negative evaluative audience, together with the monetary reward could have created a challenge state and increased motivation to do well (Mesagno et al., 2011).

5.4.2 Visual search behaviour

The changes in saliency of the task-irrelevant stimuli (larger block sizes) affected the relative time looking at the blocks. Participants visually attended significantly more often and for longer at the larger size blocks in comparison to the smaller size blocks. This would indicate that the task successfully manipulated the saliency of the task-irrelevant stimuli. In addition, the results indicate that in the high pressure condition the task-irrelevant stimuli (i.e., blocks) were attended to significantly less compared to the low pressure condition (38% reduction). This change in visual search behaviour under pressure contradicts the suggestion of the ACT. According to the ACT, anxiety influences attentional control where attention is directed away from task-relevant information (goal-directed) and more towards task-irrelevant or threatening stimuli (stimulus-driven). Changes in the influences of both these control pathways have been operationalised by the length and number of fixations on task relevant and task-irrelevant or threatening information (Nieuwenhuys & Oudejans, 2012; Wilson et al., 2009). The reduced time visually attending towards the task-irrelevant stimuli under pressure can be explained through the cue utilization theory (Easterbrook, 1959) and psychological activation theory (Yerkes & Dodson, 1908). As the pressure manipulation resulted in a moderate level of anxiety it is likely that participants performed at a more optimal level of psychological activation and associated optimal level of performance (Yerkes & Dodson, 1908). Anecdotal feedback from participants suggested that they were more motivated to do well in the high pressure setting due to the presence of the audience and the financial incentive. This increase in psychological activation can be related to narrowing of the visual attentional field resulting in a reduction in visually attending to the blocks (Easterbrook, 1959; Hüttermann & Memmert, 2014). More importantly, an increased level of psychological activation is associated with heightened attentional focus and perception of goal-relevant stimuli in comparison to less important stimuli (Chajut & Algom, 2003; Sørensen & Barratt, 2014). This suggests that under heightened psychological activation participants prioritised attending to task-relevant information (i.e., ball and hole) while reducing visually attention to task-irrelevant information (i.e., blocks). However, an increase in goal-directed visual attention towards task-relevant information (i.e., ball, hole) was not identified. Although this process seems to contradict the fundamentals of the ACT, it is important to note that support for the ACT comes from studies with paradigms where task-relevant and irrelevant stimuli carry emotional valence or play an active role in the perceptual-motor skill. In the current experiment, the blocks were emotional neutral and played a passive role in completion of the task.

The current study found no significant differences in QE period at the ball between high compared to low pressure conditions (High: 27.9 ± 14.3%, Low: 28.2 ± 11.7%). This contradicts other studies which identified that the QE period was significantly shorter under high anxiety and threat states compared to low anxiety and challenged states (Moore et al., 2012; Wilson et al., 2009). A possible explanation for this is that the length of the QE period was expressed as a percentage of the total trial time. As the trial time for the putt was significantly shorter in the high pressure condition possible differences in the absolute length of the QE period could have been marginalised. Indeed, an analysis of the differences in the absolute QE time in low pressure compared to the high pressure condition indicates a clear trend, with moderate effect size, for the QE to be shorter in the high pressure compared to the low pressure condition (High: 1.6 ± 0.7s, Low: 2.0 ± 0.9 s, $F(1,12) = 3.13$, p=.10, $\eta_p^2 = 0.21$).

5.4.3 Movement Execution

It was expected that the pressure manipulation would have a small effect on the movement execution of the putting action due to the low skill level of the participants. The results demonstrate that within the high pressure condition participants putted faster and had a more consistent execution of the putting movement (i.e., reduction in variability of speed during the downswing). Within the high pressure condition participants completed the putting task faster at the level of putter head movement time (η_p^2=0.44) and total preparation and execution time (η_p^2=0.29; table 5.1). These results support the findings of Tanaka and Sekiya (2010) and Mullen and Hardy (2000) where faster execution or responses under high anxiety conditions were identified. Of particular interest is that the decrease in movement time of the club head under high pressure was predominantly because of the shorter duration of the backswing and not the forward movement of the downswing. According to the speed-accuracy trade-off principle a similar timing of the downswing in low and high pressure would relate to akin effects on club head kinematics. Indeed, the reduction in variation in forward velocity and club head angle at impact all indicate a more consistent and efficient execution of the putts (Karlsen et al., 2008). To my knowledge no other studies have analysed face angle of the golf putter in relation to a pressure manipulation. Other studies that analysed the kinematics of the golf putt under pressure conditions found mixed results. Tanaka and Sekiya (2010) identified that participants in a high pressure condition showed a reduction in variability and amplitude in club head kinematics and Cooke et al. (2010) identified that lateral acceleration increased. These conflicting results might relate to methods used in the analysis of the club head kinematics where accelerometers or high speed cameras were used.

5.4.4 Performance outcome.

Based on the ability level of the golfers (novice) in the study and previous findings with novice golfers (Cooke et al., 2010) it was anticipated that performance outcome would not be significantly affected by the pressure manipulation. Although performance outcome was not significantly different, participants putted more accurately, as evidenced through mean radial error of the end ball location in the high compared to low pressure condition (figure 5.1). This suggests that performance effectiveness was improved in the high pressure condition. In a comparable golf putting study, Chamberlain and Hale (2007) created low, moderate and high pressure condition in which participants had to complete a golf putting task. Their results indicated that performance improved from the moderate to the high pressure condition. Other studies that have used a golf putting task to test the effects of anxiety on performance (Cooke et al., 2010; Gucciardi & Dimmock, 2008; Mullen et al., 2005; Tanaka & Sekiya, 2010) identified that anxiety did not significantly affect performance accuracy on a golf putting task. Although not supported by the directional element of anxiety, it is likely that the participants were more challenged and motivated under the high anxiety manipulation via the awarded prize money and social evaluation. Indeed, Moore et al. (2012) found that participants in a challenged state out-performed participants in a threatened state on a golf putting task. Through a set of instructions, challenge and threat states were manipulated and challenged participants demonstrated more effective gaze and putting kinematics.

The current study found differences in performance between the low and high pressure condition. The mediation analysis conducted identified a significant mediation of the variable error of the club head impact angle (*p*<.05). This suggests that the effects of the pressure manipulation on performance accuracy can be attributed to changes in variable error of the putter head angle at impact. However, due to low sample size in the current study the results of the mediation analysis should be considered with caution and requires further investigation.

5.4.5 Limitations and recommendations

The pressure manipulation adopted used variables that were successfully used in other studies (e.g., performance contingent financial incentives and self-presentation manipulations). It was expected that the negative evaluative audience acted as a social evaluative threat and therefore created anxiety. This was supported by the significant increase in cognitive and somatic anxiety in the high pressure condition. However, participants did not evaluated the anxiety as more debilitative to their performance (see table 5.1). This could highlight that the audience, together with the monetary reward created a challenge state and more motivation to do well (Mesagno et al., 2011). Therefore, it is recommended to include a post pressure manipulation evaluation of the experienced challenge or threat (Rossato et al., 2016). As the participants were novice golfers it was assumed that they held low expectations to be successful in this task. Therefore, the comments of the audience might not have influenced their self-presentation as much, if compared to more experienced golfers.

Within the study, it was identified that participants looked significantly less at the blocks on the green in the high pressure condition. This was in contrast with the hypothesis that these blocks would attract more visual attention in the high pressure condition due to their potential threat to performance. To some extent, the saliency of the blocks was manipulated by changing the size (e.g., participants looked significantly more at larger sized blocks than smaller sized blocks). However, a post-trial self-reported evaluation of the perception of the blocks could have examined how participants acted and reacted to the presence of the blocks. As the blocks played a relative passive role in the completion of the task it is of interest to examine how this would relate to more salient stimuli that would play a more imminent role in the completion of a motor skill.

5.5 Conclusion

The findings of the current study further enhance the understanding of the role of pressure on visually attending to task-relevant and irrelevant stimuli. Where previous studies predominantly examine how pressure effects performance and visual attention to task-relevant stimuli, the current study investigated visual attention towards task-relevant and passive irrelevant stimuli in golf putting. In contrast to studies examining changes in visual attention towards task-relevant stimuli, the findings of the current study indicate that participants looked less at task-irrelevant stimuli under high pressure, compared to low pressure conditions. In addition to changes in visual search behaviour the participants putted faster with reduced variability (i.e., variable error of impact angle, SD of forward velocity of the downswing) in the high pressure compared to the low pressure condition. This combination of effects resulted in an improvement in performance as expressed by the mean radial error of the end location of the ball. However, the results from chapter 4 of this thesis identified that participants in a high pressure condition demonstrated inter-individual differences in endocrine reactivity. These inter-individual differences in endocrine reactivity (i.e., changes in sAA and cortisol) are indicative of the interpretation of the social evaluative manipulation into a challenged or threatened state. Experiencing a challenged state in high-pressure conditions is predicted to have a positive influence on performance, whereas a threatened state would negatively influence performance (Hase et al., 2018). Hence, the inter-individual differences in performance and direction of visual attention towards task-irrelevant stimuli in the high-pressure condition could be related to these challenged on threatened states. Additionally, the direct influence of endocrine reactivity on the stimulus-driven attentional system provides a theoretical explanation for the changes in visual search behaviour. Therefore, it is of interest to examine what the role of these individual differences in endocrine reactivity, as an indicator of threatened-challenged states, are on visual search behaviour and performance execution, which was the aim of chapter 6.

Chapter 6: The influence of biological stress reactivity on performance, performance execution and the direction of visual attention

6.1 Introduction

The effects of emotional states on sport performance have extensively been examined within the sport psychology domain (Craft et al., 2003; Woodman & Hardy, 2003). However, the role and relationship between psychophysiological measures of stress and sport performance are not regularly examined. Negative emotions that develop when completing motor skills under motivated and social-evaluative conditions concurrently trigger a biological stress response reflected in activation of the HPA-axis and SNS. The salivary biomarkers of HPA-axis activation (i.e., cortisol) and SNS activation (i.e., sAA) allows for the limited invasive assessment of these stress pathways to examine its potential effect on sport performance. Particularly the reactivity of the hormone cortisol has been examined in real sport competitions in relation to the final outcome (Gonzalez-Bono et al., 1999) or game location (Carré et al., 2006). Evidence from these studies, and several reviews (L. D. Hayes et al., 2015; Salvador, 2005), indicate that cortisol increases from pre to post sport competition, however limited support is identified for the relationship between cortisol and sport performance (Casto & Edwards, 2016). This can partially be explained due to the sensitivity of used performance measures. Game outcome is affected by a plethora of factors such as quality of the opponent, ability, luck, in addition to the experienced stress. Secondly, within these studies cortisol concentration is typically assessed post competition, where it is expected that the physiological intensity of the activity effects cortisol more than the experienced stress (see chapter 1). However, experimental chapter 2 of this thesis identified that athletes experience a significant endocrine response in anticipation to participation in real sport competition, evidenced by a significant increase in cortisol. The magnitude of this anticipatory stress response reflects the personal importance of the competition as well as the expected social-evaluation of performance in comparison to others and challenge and threat states, which can explain the great inter-individual variation in the anticipatory cortisol response. Within chapter

4 of this thesis it was identified that cortisol and sAA can be successfully activated in a competitive laboratory environment by adopting Baumeister and Showers' (1986) suggested methodological approaches of a combination of self-presentation and motivational stimuli of financial incentives, performance evaluation and an audience. However, chapter 4 identified great inter-individual variability in the endocrine response, particularly reflected in significant differences in cortisol reactivity between participants. As cortisol is suggested to affect sport performance through its influence on the motor cortex and cerebellum via cortico-cortical input (Hatfield et al., 2013) and the PFC associated with executive control and inhibition (Shields et al., 2015) it is of interest to examine the relationship between inter-individual differences in stress reactivity and performance execution and visual attention in perceptual-motor skills.

Studies examining the effects of anxiety on visual attention and sport performance in laboratory environments typically create a pressure manipulation by combining motivational incentives and self-presentation components (Mesagno et al., 2011). In contrast, several studies that examine cortisol reactivity and sport performance in laboratory environments use solely self-presentation stressors (TSST, Mascret et al., 2016), cardiovascular stressors such as the cold pressor task (CPT, Lautenbach, 2017) or a mental arithmetic task (Lautenbach et al., 2014), that reliable activate the HPA-axis (Dickerson and Kemeny, 2004). These stressors, unrelated to motor skills performance, are used to activate the HPA-axis with the aim to test whether cortisol concentration affects sport performance. For example, Lautenbach (2017) examined the effects of inducing stress via a CPT on golf putting performance. The CPT significantly increased cortisol levels in comparison to a control condition, where performance outcome (e.g., nr of puts made out of 10), assessed 15 minutes after the CPT or a control condition, was not affected by cortisol. Lautenbach (2017) postulated that the artificial nature of the pressure manipulation (i.e., it was not related to performance in the golf putting task) explained that cortisol did not affect sport performance. Alternatively, it seems plausible that the outcome measure of performance was not sensitive enough to identify changes in performance. The effects of cortisol on sport performance would initially affect the coordination of the movement and variability in movement execution, before influencing performance outcome (Hatfield et al., 2013). In addition, increased cortisol can affect the direction of visual attention to task-relevant and irrelevant information, however this was not examined by Lautenbach (2017). Similarly, in a repeated measures crossover design, Mascret et al. (2016) exposed participants to either a TSST or a placebo trial, to examine the effects of this psychosocial stressor on basketball free throw shooting performance and execution. Cortisol concentration significantly increased following completion of the TSST, however, this did not affect shooting performance. In contrast, under the placebo condition, with lower cortisol levels, performance outcome significantly decreased despite not identifying changes in performance execution measures. A characteristic of the aforementioned studies using these stress manipulations (i.e., CPT and TSST) to induce stress is that the task performance (i.e., golf putting or basketball free throw performance) was completed under neutral conditions. As suggested by Lautenbach (2017), to examine the influence of the endocrine response in sport performance it is recommend to associate the task to the stress manipulation to ensure meaning. Although the studies above highlight the effectiveness of increasing cortisol, both did not attempt to analyse the role of inter-individual differences in reactivity. Participants completing a TSST and CPT manipulation will not respond uniformly. Large inter-individual differences in cortisol reactivity are expected and identified. For example, the results of Mascret et al. (2016) identified large variability in cortisol reactivity as evidence through a coefficient of variation of 45% in cortisol concentration post TSST. Although some of these inter-individual differences can be controlled in experimental design (e.g., gender, experience and age) several other are more challenging to control (e.g., coping abilities, genetic influence and heredity). Hence, a grouping of participants in those who responded strongly to the manipulation in comparison to those who do not can highlight whether reactivity, in contrast to magnitude change, would affect performance and performance execution (Elzinga & Roelofs, 2005; Miller et al., 2013; Nater et al., 2007; Schwabe, Haddad, & Schachinger, 2008).

Where adopting psychosocial manipulations from the psychology domain (e.g., TSST) is successful in inducing stress, combining self-presentation and motivational components (e.g., financial incentives and an audience) related to the completion of a perceptual-motor skill are more difficult in inducing an endocrine response. Although these manipulations can activate the HPA-axis and SNS, the identified magnitude is typically below that reported in TSST (see chapter 4). The influence of SNS or HPA-axis activation on sport performance are regularly examined, however, none have examined the combined effects of stress reactivity on visual attention and performance execution. The influence of HPA-axis activation on sport performance can be explained through a direct influence of cortisol on cerebral cortical activation. Here, cortisol will create extra neurological input in the motor cortex and cerebellum, where the refinement of the execution of the motor skill is impaired (Hatfield et al., 2013). The effects of these small refinement are more prominent in fine motor skill in comparison to gross motor skills, therefore changes in cortisol are most likely to influence the performance in fine motor skills such as darts and golf putting in contrast to gross motor skills such as weight lifting. Indeed, Casto and Edwards (2016) highlight that cortisol has a positive influence on weight lifting performance where it negatively influences aiming and reach and grasp tasks. In addition to a direct influence of cortisol on brain regions associated with motor control, cortisol is also expected to influence the stimulus-driven and goal-directed attentional systems through its influence on the PFC. Within the PFC, cortisol can influence the inhibition function of the central executive. Studies have identified that a moderate level of cortisol is associated with enhanced pre-potent motor response and resistance to distractor interference inhibition (Schwabe et al., 2013; Shields et al., 2015; Taylor et al., 2011), in comparison to low and high levels of cortisol. This is reflected in quicker response time to identify task-relevant information together with enhanced response accuracy in tasks assessing pre-potent response inhibition (Schwabe et al., 2013). If cortisol influences inhibition, where participants with high cortisol are more likely to demonstrate enhanced inhibition of task-irrelevant information, it is likely that the saliency of the information on the environment will influence this. Within chapter 5 of this thesis, it was identified that under high pressure participants attended significantly less to task-irrelevant information (i.e., blocks) on the putting green, in comparison to a low pressure condition. However, the manipulation of the saliency of this information (different size blocks) influenced the task constraints (different size gaps were created for the ball to pass through). By creating task-irrelevant stimuli of different saliency, whilst maintaining similar task constraints (i.e., same gap width), it is possible to examine the role of cortisol on the inhibition function in perceptual-motor tasks and additionally examine the influence of saliency on this. To this extent two different saliency conditions were created by different type of blocks. The large blocks, used in chapter 5, and a cluttered block condition, created by a group of small cubes, on the lateral sides of the imaginary line between ball and target location (see figure 6.2). The cluttered block condition aimed to create a crowded scene. Visual crowding relates to a decrease in object recognition in the peripheral visual field (Whitney & Levi, 2011). Crowding is partly caused by the decline in visual acuity in the peripheral visual field. More specifically, object feature discrimination is affected by density of surrounding objects as well as the distance between target (e.g., gap) and surrounding objects. In other words, object feature recognition increases when the distance between surrounding objects is increased. It was hypothesized that the cluttered scene would attract more overt visual attention as it is more difficult to identify the exact properties of the presented information (e.g., exact position of small blocks and gap). In contrast, the two large blocks were consistent in their appearance making it easier to differentiate the task-relevant (e.g., gap) and irrelevant information (e.g., blocks) in the visual scene. These different blocks condition, of different saliency, were positioned at similar propinquity on the putting green to maintain constant task constraints to examine the role of cortisol on visual attention to these sources of task-irrelevant information. Therefore, the aim of this study was to examine the influence of stress reactivity on performance, performance execution and visual attention to task-relevant and irrelevant information.

6.2 Methods

6.2.1 Participants

Forty one male participants (M = 21.0 years, SD = 3) from a sport and exercise student population volunteered to participate in the study. All participants were right handed, had normal or corrected to normal vision and were considered novice golfers with no golf or golf putting experience. The tenants of the Declaration of Helsinki were observed and the experiment received institutional ethical approval. The participants provided written informed consent before participation.

6.2.2 Research Design

The experiment was designed to assess whether stress reactivity of participants influenced performance, performance execution and visual attention in a golf putting task with task-irrelevant information. To answer this question all participants completed 15 golf putts under the high pressure condition (as outlined in the general method) towards a circular target area, of the width of a standard size hole (10.8 cm diameter, 0.0 cm depth). The golf putting equipment as outlined in the general method was used. Within the trial participants completed 3 sets of 5 putts in a randomised order. Two sets of putts had blocks on the putting green, which were positioned on both sides of the putting green halfway (1.75 m) from the target and acted as the task-irrelevant sources of information, where 1 set of 5 putts, the control condition, had no blocks positioned on the green. The large block condition consisted out of a pair of white blocks of 30cm width and 7cm height, creating a gap of 15cm for the ball to pass through (see figure 6.1).

Figure 6.1 Large block condition

A cluttered block condition was created by positioning 2 groups of 7 small cubes (2x2x2 cm) in a V-formation on both sides of the green. The positioning of the two groups of 7 small cubes created a gap of 15cm for the ball to pass through, identical to the large block condition (see figure 6.2).

Figure 6.2 Cluttered block condition

The two different block conditions were included to act as task-irrelevant sources of information. By maintaining a similar gap for the ball to pass through, it was ensured that task constraints were constant in between the two block condition, however, the saliency of the distractor was changed. The individual cubes in the cluttered block condition had a size of 0.65° where the gaps in between the small cubes had a size of 2.40°. The created cluttered scene, and ratio of 3.7° between gaps and cubes, is identical in set-up to Vlaskamp, Over and Hooge (2005) with the exception that the current experiment did not require participants to identify the features of the cluttered scene.

6.2.3 Self-reported measures

State anxiety: State anxiety was assessed immediately before the putting trial (-5 minutes) with the modified Competitive State Anxiety Inventory-2 (Martens et al., 1990). The CSAI-2 had an acceptable internal consistency varying from Cronbach alpha scores from .82 to .86 for the three constructs, comparable to values previously reported by Martens, Vealey, & Burton (1990). The directional element had acceptable internal reliability scores varying from .76 to .80, in the range reported previously (Jones & Uphill, 2004). The MRF-Likert (Krane, 1994) was administered during the putting task. After completing 10 putts the participants were directed to side of the laboratory, away from the audience, to complete the three questions on the MRF-Likert. Internal reliability of the MRF was not assessed due to constructs consisting out of one item.

Challenge and Threat: An adjusted version of the 12 item CAT-Sport (Rossato et al., 2016) was used to measure the experience of challenge and threat states retrospectively (e.g., immediately after completing the trial). The internal reliability of the 7 items assessing threat had an acceptable Cronbach alpha of .86. In contrast, the 5 items related to the measurement of challenge had a below acceptable Cronbach alpha value (α =.53). Removing one of the items did not bring Cronbach alpha to an acceptable level. The challenge item was therefore removed from the analysis and only the experience of threat was used in the analysis.

6.2.4 Performance Outcome

The change from a hole (chapter 5) to a target, made the performance measure more continuous and therefore sensitive to small changes in movement execution at the expense of losing the outcome measure of performance (e.g., only 5 out of the 615 completed putts landed on the target). Differences in the number of successful putts (e.g., performance outcome) was not analysed due to the low number of putts that ended on the target. Performance accuracy was expressed as the mean radial error derived from the end ball location in respect to the centre of the target (see general method for details on how this was measured and calculated). When putts were long and went off the green the location of the instance of leaving the green was used to determine the distance from the target. A ball that deflected from the blocks, went through the small cubes in the cluttered condition or hit the large blocks were excluded from the analysis. Therefore, a low performance score indicates an end location closer to the target (i.e., increased performance accuracy). Performance consistency in the end location of the ball in the control and two block conditions was expressed as the bivariate variable error (BVE) as outlined in the general method.

6.2.5 Movement execution

The club head movement during the golf putt was assessed with a three-dimensional motion analysis system (Codamotion, Charnwood Dynamics Ltd, Leicestershire, UK) and collected and processed as outlined in the general method.

6.2.6 Visual Attention

To assess visual attention all participants wore a SMI mobile eye gaze registration system (IviewETG, SensoMotoric instruments Inc, Teltow; Germany, Ver. 1.0). The data collection and analysis were completed according to the procedures outlined in the general method. A random selection of trials (10%) was coded by two researchers. An excellent average intraclass correlation coefficient of 0.94 was observed the frame-by-frame mapping of the areas of interest ball (0.90, CI: 0.81-0.94) and target (0.98, CI: 0.91-0.97).

6.2.7 Cortisol and sAA

Cortisol and sAA concentration were derived from saliva samples. The findings of chapter 4 highlighted two elements that warranted the amendment of the collection protocol presented in the general method. Firstly, within chapter 4, both cortisol and sAA concentration were stable from 20 to 40 minutes post trial. Secondly a sub-group of participants had significantly increased cortisol levels on arrival in the laboratory and did not show cortisol reactivity to the pressure manipulation. In contrast, a responding sub-group of participants had low levels of cortisol on arrival and demonstrated cortisol reactivity to the task (see chapter 4). This could indicate that the early anticipation to completing the golf putting task influenced cortisol reactivity, hence an amendment to the saliva collection schedule was implemented. More specifically, a saliva baseline sample was collected on a resting day, time matched with the pressure manipulation to correct for circadian rhythms. The change in cortisol and sAA from around the golf putting task to cortisol and sAA in the baseline sample, would indicate endocrine reactivity. Hence, three saliva samples were collected around completing the golf putting task. Immediately before completing the putting task (e.g, ± 5 minutes before the trial), immediately after completing the putting task (+1 minute) and 20 minutes after completing the trial (see figure 6.3). The baseline saliva sample was collected on a neutral day, time matched to the time of day when the trial was completed and separated by at least 7 days from the trial. In comparison to chapter 4 in this thesis the 30 minutes before the trial and 40 minutes post trial samples were removed and replaced by a resting sample in the current study. All saliva samples were provided whilst seated in a secluded area of the laboratory.

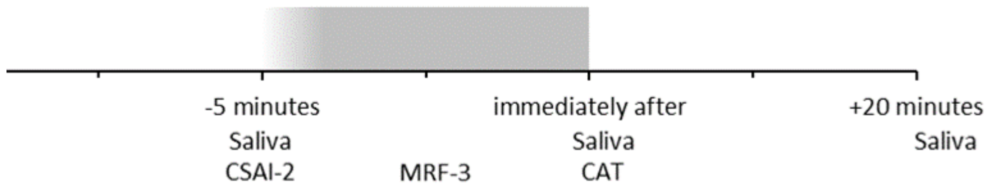

Figure 6.3 Timeline of the data collection procedures in relation to the golf putting task (grey area). Competitive State Anxiety Inventory (CSAI-2), Mental Readiness Form (MRF-3), Challenge and Threat Scale (CAT).

The aim was to group participants into two groups with low and high cortisol reactivity based on Miller's (2013) classification of 1.5nmol/l change from baseline to peak level around the stress manipulation. Due to participant drop-out following completion of the golf putting trial only 24 of the 41 participants provided these baseline saliva samples. Moreover, and in contrast to the expectation, baseline levels of cortisol (n=24), showed great intra-individual variation in comparison to the cortisol concentration around the golf putting trial. The baseline level of cortisol from 15 participants (63%) were higher than recorded during the trial, whereas baseline cortisol of 9 participants (27%) were lower than one or more samples collected around the golf putting trial. Hence, the baseline samples of cortisol were excluded from the analysis and a grouping of participants based on changes in cortisol over the 3 saliva collection time points was conducted. Participants were retrospectively grouped into two categories of cortisol reactivity. Participants were categorised in a high cortisol group (HCG) when cortisol concentration at -5 minutes was at least 1.5nmol/l higher than consecutive time points (Miller et al., 2013), where the mean increase in cortisol was +1.84 ± 2.1 nmol/l. Participants were grouped into a low cortisol group (LCG) when cortisol concentration at -5 minutes was lower than immediately after the trial and/or 20 minutes after the trial (mean cortisol was -1.25 ± 1.15 nmol/l lower than consecutive collection points).

6.2.8 Statistical analysis

All analysis were conducted in SPSS for Windows, Version 20.0 (Armonk, NY: IBM Corp). To ascertain whether learning effects affected performance outcome, analysis was conducted on the repetition effect between the performance (i.e., radial error) off the first putt, the 7^{th} putt and the last putt of the trial. There was no significant effect of repetition on putting performance (p>.05). Both cortisol and α-amylase were not normally distributed. A log transformation was applied to correct for a positive skew in cortisol and sAA. Independent samples *t*-tests were conducted to examine whether the self-reported measures of anxiety and threat were different between cortisol groups. Differences between groups in cortisol and sAA at the different time collection points were analysed with a 2 (saliva groups) by 3 (saliva collection time points) repeated measures ANOVA. Differences between cortisol and sAA groups and performance accuracy, performance execution and visual attention were assessed with a 2 (cortisol groups) by 3 (block conditions) repeated measures ANOVA. Simple contrasts were used to identify differences between groups and pairwise comparisons with Bonferroni correction for within group effects. Effect sizes for repeated measures analyses are reported as partial eta squared (η_p^2). All figures of cortisol and α-amylase levels present the original, non-log transformed data.

6.3 Results

6.3.1 Cortisol

No significant main effect was identified between the cortisol concentration of 22 participants in the HCG compared to 19 participants in the LCG ($F(1,39)=0.84$, $p=.37$, $\eta_p^2=.021$). Salivary cortisol had a significant time effect, ($F(2,78)= 7.20$, $p=.001$, $\eta_p^2=.16$) where cortisol before the trial was significantly higher than 20 minutes after ($p=.012$) and cortisol immediately after the trial was significantly higher than 20 minutes after ($p=.002$). A time by cortisol group interaction effect ($F(2,78)= 29.09$, $p<.001$, $\eta_p^2=.43$), supported the identification of participants into distinct groups of high and low cortisol concentration during the trial. Cortisol concentration in the HCG was significantly higher than the LCG before the trial (-5 minutes, $p=.004$) but no significant differences were identified at other time points. In addition, the HCG had significantly higher cortisol levels before the trial compared to immediately after ($p<.001$) and 20 minutes after ($p<.001$) and cortisol concentration immediately after was significantly higher than 20 minutes after ($p=.009$). The LCG had significantly lower cortisol before the trial in comparison to immediately after the trial ($p<.001$) and 20 minutes after the trial ($p=.009$) and cortisol immediately after the trial showed a trend to be significantly higher than 20 minutes after the trial ($p=.051$). (See figure 6.4 below)

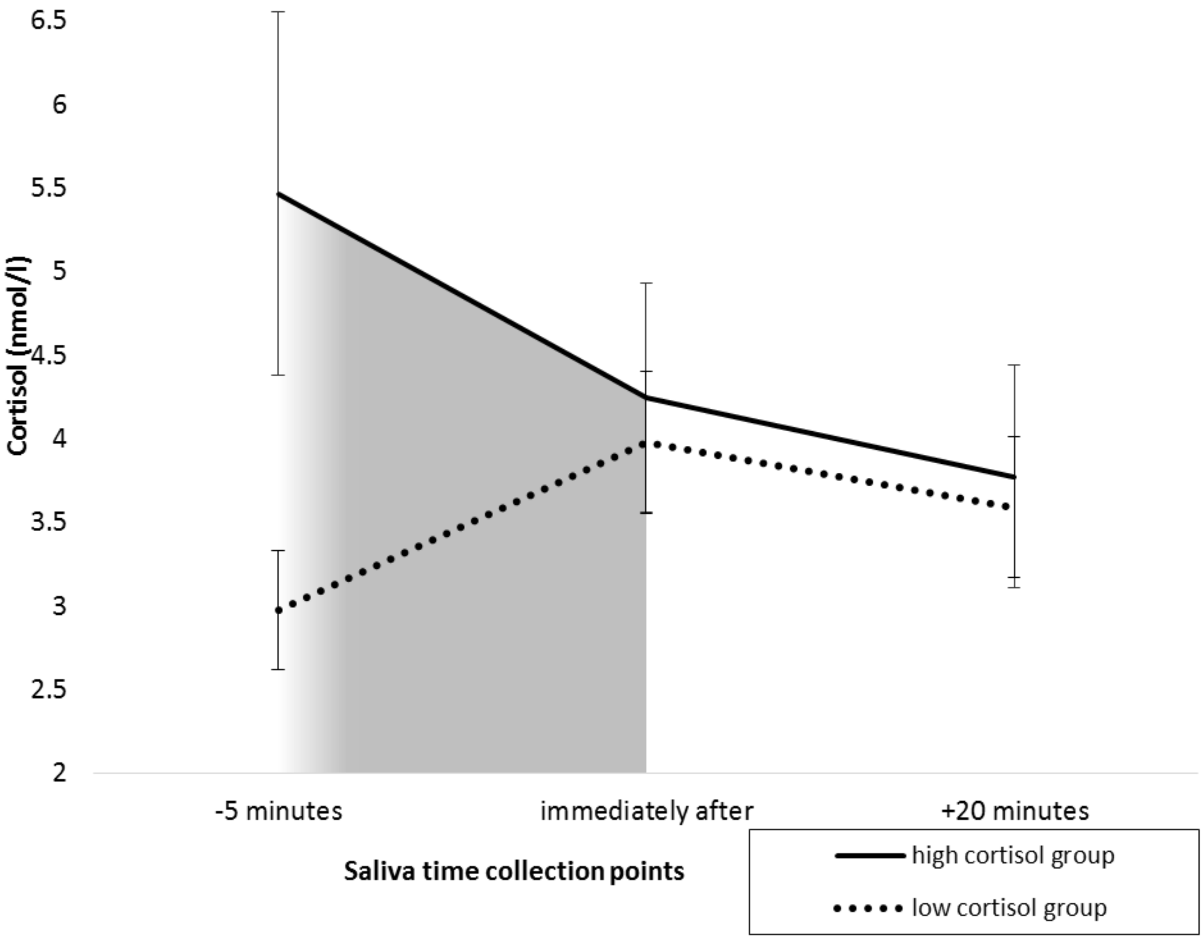

Figure 6.4 The cortisol concentration in saliva (nmol/l) at the 3 time collection points for the high and low cortisol group (M ± SE). Shaded area denotes period of golf putting task.

6.3.2 sAA

There was no significant difference in sAA between cortisol groups (F(1,39)=0.02, p=.899, η_p^2=.00), between different time collection points, (F(2,78)=0.85, p=.43, η_p^2=.02) or time by cortisol group interaction effect (F(2,78)=0.27, p=.77, η_p^2=.00).

6.3.3 Self-reported measures and cortisol reactivity

The analysis of differences between the HCG and LCG in self-reported measures identified that cognitive anxiety (CSAI-2), assessed before the task, was significantly higher in the HCG group compared to the LCG (t(39)=2.08, p=.044, r=0.32). In contrast, somatic anxiety (p=.31) and self-confidence (p=.49) were not significantly different between the HCG and LCG. There were no significant differences between the directional elements of the CSAI-2 constructs (p>.05) between the HCG and LCG. The differences between the HCG and LCG were not present in the assessment of state anxiety during the task (MRF, *p*>.05) and did not related to differences in interpretation of the task as being more threatening (CAT-Scale, *p*>.05), see table 6.1

Table 6.1 Mean (M) and standard deviation (SD) of self-reported measures of anxiety before the trial (CSAI-2), during the trial (MRF-3) and threat evaluation (CAT) after the trial, for the high cortisol group, low cortisol group and whole population.

	HCG		LCG		Group	
	M	SD	M	SD	M	SD
CSAI-2 intensity cognitive (9-27)	17.0*	5.4	13.7	4.6	15.4	5.3
CSAI-2 intensity somatic (9-27)	14.4	4.6	13.1	3.0	13.8	3.9
CSAI-2 directional cognitive (-27-27)	-1.6	5.0	-1.3	5.4	-1.5	5.1
CSAI-2 directional somatic (-27-27)	0.8	5.3	0.7	5.6	0.8	5.4
MRF cognitive (1-11)	4.8	2.3	4.3	2.1	4.6	2.2
MRF somatic (1-11)	5.4	2.3	4.7	2.0	5.1	2.2
MRF self-confidence (1-11)	5.8	1.5	5.0	1.9	5.4	1.7
CAT threat (1-7)	2.1	1.0	2.2	0.9	2.1	0.9

Note. Higher values on the intensity scale of CSAI-2 and MRF indicates greater anxiety scores. A negative score on the directional rating of the CSAI-2 indicates more negative effects of anxiety. Higher scores on MRF self-confidence scale indicates less confidence. Higher scores on the CAT scale indicates more threatened. * Significantly different from LCG, *p*<.05

6.3.4 Cortisol grouping and performance

The MRA of the end ball location was significantly higher (i.e., further away from the target) in the HCG (M = 49.0 ± 12.2 cm) compared to the LCG (M = 40.5 ± 12.2 cm, $F(1,39)=4.86$, $p=.03$, $\eta_p^2=.11$), indicating that participants with high cortisol performed worse than participants with low cortisol levels. A significant effect for condition was identified ($F(2,78)=7.43$, $p=.001$, $\eta_p^2=.160$), where end ball location was significantly closer to the target in the control condition, without blocks, compared to large block condition (p=.001) but no significant difference between the control and cluttered block condition was identified ($p=0.07$). There was a trend for end ball location to be closer to the target in the cluttered block condition compared to large block condition (p=.05). No significant cortisol groups by condition interaction effect was identified ($F(2,78)=2.32$, p=.10, η_p^2=.06), see figure 6.5.

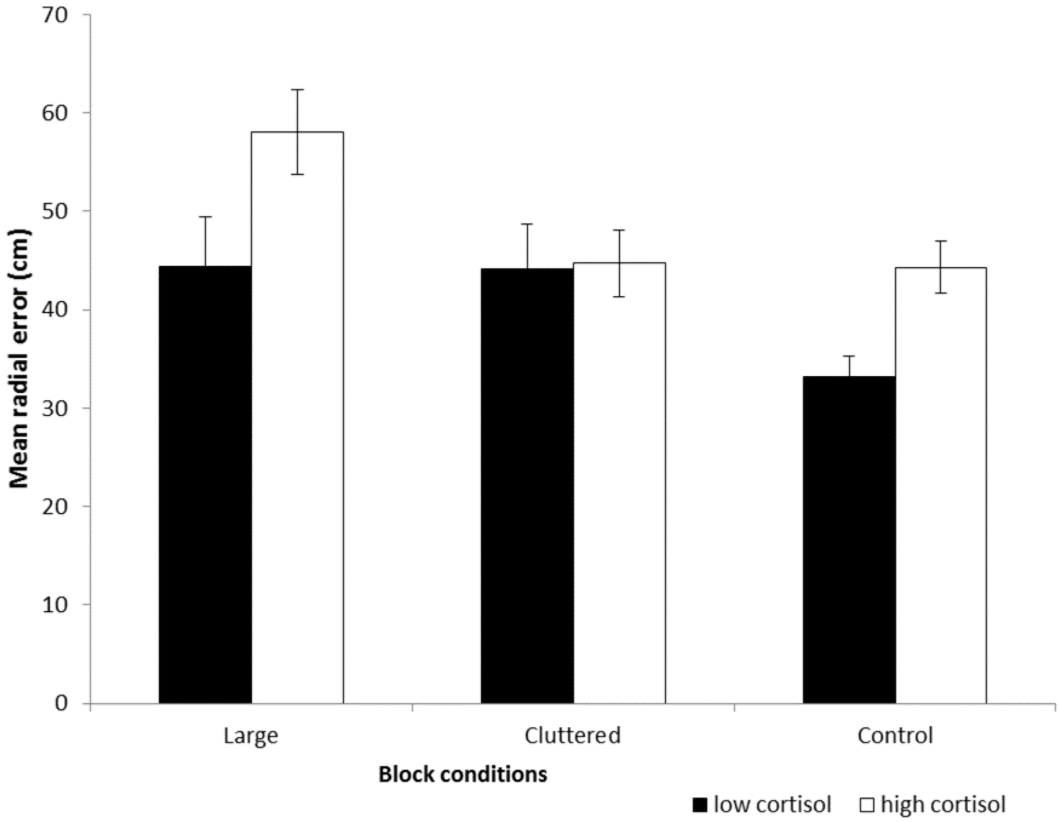

Figure 6.5 Mean radial error of the end ball location in the LCG and HCG for the large, cluttered and control condition respectively (M ± SE). LCG: Black bars, HCG: White bars.

The BVE of the end ball location was not significantly different between the HCG and LCG ($F(1, 39)$=.88, p=.35, η_p^2=.02). No significant effects for condition ($F(2,78)$=.001, p=.99, η_p^2 =.00) or cortisol groups by condition interaction effect ($F(2,78)$=.32, p=.73, η_p^2=.01) were identified.

Movement execution

Due to a faulty marker, the angular club head kinematics of one participant were not collected. The angular data of this participant was replaced by the population average.

Preparation time: The time to complete the putt (from aligning the club head with the ball, preparing the shot, to striking the ball) was not significantly different between the HCG and

LCG ($F(1, 39)=2.36$, $p=.13$, $\eta_p^2=.06$). A significant effect for condition was identified ($F(2,78)=5.15$, $p=.008$, $\eta_p^2=.12$) where trial time was significantly shorter in the control condition compared to the large block condition (p=.002) but not between other conditions (p>.05). No significant cortisol groups by condition interaction effect ($F(2,78)=1.7$, $p=.19$, $\eta_p^2=.04$) was identified.

Execution time: The time to execute the putting movement (combined backward-forward putter movement) was not significantly different between the HCG and LCG ($F(1,39)=0.64$, $p=.43$, $\eta_p^2=.02$). In addition, no significant differences between conditions ($F(2,78)=.83$, $p=.44$, $\eta_p^2=.02$) or cortisol groups by condition interaction effects ($F(2,78)=.00$, $p=.99$, $\eta_p^2=.00$) were identified. There was a significant difference in the downswing time between the HCG and LCG ($F(1, 39)=4.08$, $p=.05$, $\eta_p^2=.10$), where the HCG had a shorter downswing time than the LCG. In addition, a significant effect for condition was identified ($F(2,78)=3.92$, $p=.02$, $\eta_p^2=09$) where downswing time was significantly shorter in the large block condition compared to the control condition ($p=.002$) and cluttered block condition ($p=.04$) but not between the control and cluttered block condition ($p=.82$). No significant cortisol groups by condition interaction effect ($F(2,78)=0.60$, $p=.94$, $\eta_p^2=.00$) was identified. There was no significant difference in backswing time between the HCG and LCG ($F(1,39)=0.02$, $p=.90$, $\eta_p^2=.00$) and no significant differences between conditions ($F(2,78)=0.57$, $p=.57$, $\eta_p^2=.01$) or cortisol groups by condition interaction effects ($F(2,78)=0.01$, $p=.99$, $\eta_p^2=.00$) were identified. See table 6.2

Table 6.2 Mean (M) and standard deviation (SD) of performance measures and temporal in the HCG and LCG in the three different putting conditions.

	Large blocks		Cluttered Blocks		Control condition	
	M	SD	M	SD	M	SD
Mean radial error (cm)						
HCG	58.1	20.2	44.7	15.9	44.3	12.5
LCG	44.4	22.1	44.2	19.4	33.2	8.7
BVE error (cm)						
HCG	34.4	11.6	35.6	12.3	36.4	9.6
LCG	34.1	15.5	32.9	15.0	32.2	9.0
Preparation time (s)						
HCG	5.2	1.7	4.6	1.6	4.3	1.0
LCG	4.2	1.4	4.2	0.8	3.9	1.7
Execution time (s)						
HCG	0.83	0.15	0.84	0.15	0.84	0.14
LCG	0.86	0.13	0.88	0.14	0.87	0.13
DS time (s)						
HCG	0.27	0.05	0.27	0.05	0.28	0.05
LCG	0.30	0.05	0.31	0.05	0.31	0.06
BS time (s)						
HCG	0.56	0.11	0.57	0.11	0.56	0.10
LCG	0.57	0.09	0.57	0.09	0.56	0.08

Note. BVE = bivariate variable error, DS = downswing, BS = backswing.

Club head kinematics

There was no significant difference between the HCG and LCG in the length of the backswing $F(1,39)=2.64$, $p=.11$, $\eta_p^2=.06$. No significant effect of conditions ($F(2,78)=0.05$, $p=.95$, $\eta_p^2=.00$) or cortisol groups by condition interaction effects ($F(2,78)=0.15$, $p=.86$, $\eta_p^2=.00$) were identified.

There was no significant difference between the HCG and LCG in the instantaneous velocity deviation in forward direction during the downswing ($F(1,39)=0.16$, $p=.69$, $\eta_p^2=.00$). A significant effect of condition ($F(2,78)=19.82$, $p<.001$, $\eta_p^2=.34$) was identified, where the instantaneous velocity deviation in forward direction during downswing was lower in the control condition compared to the cluttered block (p=.002) and large block condition (p<.001). In the cluttered block condition the instantaneous velocity deviation in x-velocity during the downswing was significantly lower than the large block condition (p=.003). No significant cortisol groups by conditions interaction effect was found (F(2,78)=.30, p=.74, η_p^2=.01).

There was no significant difference between the HCG and LCG in the instantaneous velocity deviation in lateral direction during the downswing (F(1,39)=2.08, p=.16, η_p^2=.05) and no significant differences between conditions (F(2,78)=0.06, p=.95, η_p^2 =.00) or cortisol groups by condition interaction effects (F(2,78)=1.51, p=.23, η_p^2 =.04) were identified.

Ball impact

The impact angle was not significantly different between the HCG and LCG (F(1,39)=0.06, p=.81, η_p^2=.00). No significant effect of condition (F(2,78)=2.23, p=.11, η_p^2=.05) or cortisol groups by condition interaction effects (F(2,78)=1.09, p=.34, η_p^2=.03) were identified.

There were no significant differences between the HCG and LCG in the variable error of the impact angle (F(1,39)=0.15, p=.70, η_p^2=.004). No significant effect of condition (F(2,78)=1.9, p=.16, η_p^2=.05) or cortisol groups by condition interaction effects (F(2,78)=1.52, p=.22, η_p^2=.04) were identified for the VE of the impact angle.

The forward velocity at ball impact was not significantly different between the HCG and LCG (F(1,39)=0.48, p=.50, η_p^2=.01). A significant effect for condition was identified (F(2,78)=23.46, p<.001, η_p^2=.38) where forward velocity at impact was significantly faster with large blocks, compared to cluttered blocks (p=.003) and control condition (p<.001). The forward velocity at impact with cluttered blocks was significantly faster than the control condition (p=.001). No significant cortisol groups by condition interaction effect (F(2,78)=0.42, p=.66, η_p^2=.01 was identified.

There was a significant difference in the lateral velocity (y-velocity) at ball impact between the HCG and LCG (F(1,39)=4.60, p=.04, η_p^2=.10) where the HCG had lower lateral velocity than the LCG. No significant effect for condition ($F(1.7,67.8)=0.70$, $p=.48$, $\eta_p^2=.02$) and cortisol groups by condition interaction effects ($F(1.7,67.8)=0.72$, $p=.48$, $\eta_p^2=.02$) were identified.

The variable error in x-velocity at impact was not significantly different between the HCG and LCG ($F(1,39)=1.34$, $p=.26$, $\eta_p^2=.03$). No significant effect of condition ($F(2,78)=1.56$, $p=.22$, $\eta_p^2=.04$) or cortisol groups by condition interaction effects ($F(2,78)=.36$, $p=.70$, $\eta_p^2=.01$) were identified.

The variable error in the y-velocity at impact was not significantly different between the HCG and LCG ($F(1,39)=1.7$, $p=.21$, $\eta_p^2=.04$). No significant effect of condition ($F(2,78)=0.36$, $p=.70$, $\eta_p^2=.01$) or cortisol groups by condition interaction effects ($F(2,78)=.03$, $p=.97$, $\eta_p^2=.00$) were identified. See table 6.3

Table 6.3 Mean (M) and standard deviation (SD) of club head kinematics in the HCG and LCG in the three different putting conditions.

	Large blocks		Cluttered Blocks		Control condition	
	M	SD	M	SD	M	SD
BS length (cm)						
HCG	234.5	60.6	235.9	64.0	235.6	68.0
LCG	270.6	68.1	266.8	71.1	265.7	72.2
SD X-velocity DS						
HCG	0.54	0.05	0.51	0.05	0.50	0.03
LCG	0.53	0.05	0.51	0.04	0.49	0.04
SD Y-velocity DS						
HCG	0.04	0.01	0.04	0.02	0.03	0.01
LCG	0.04	0.02	0.04	0.02	0.05	0.02
X-axis impact velocity ($m.s^{-1}$)						
HCG	1.60	0.13	1.52	0.12	1.47	0.08
LCG	1.57	0.15	1.52	0.10	1.44	0.06
Y-axis impact velocity ($m.s^{-1}$)						
HCG	0.00	0.08	0.01	0.07	-0.01	0.08
LCG	-0.05	0.09	-0.05	0.07	-0.05	0.09
VE X-impact velocity ($m.s^{-1}$)						
HCG	0.12	0.06	0.12	0.07	0.11	0.04
LCG	0.11	0.06	0.10	0.06	0.09	0.04
VE Y-impact velocity ($m.s^{-1}$)						
HCG	0.05	0.02	0.05	0.03	0.05	0.03
LCG	0.04	0.03	0.04	0.02	0.04	0.01
Impact angle (°)						
HCG	180.89	1.18	181.26	1.09	180.69	1.15
LCG	181.01	1.51	180.87	1.68	180.69	1.62
VE impact angle (°)						
HCG	1.23	0.50	1.21	0.55	0.93	0.51
LCG	1.12	0.69	1.27	0.82	1.16	0.50

Note. BS = backswing, DS = downswing, X = forward direction, Y = Perpendicular to putting line, VE = variable error.

6.3.5 Visual Search behaviour

Scan rate

There was no significant difference in scan rate between the HCG and LCG ($F(1,39)=0.84$, $p=.37$, $\eta_p^2=.02$). A significant difference between conditions ($F(2,78)=30.8$, $p<.001$, $\eta_p^2=.44$)

identified that scan rate was significantly higher in the large block condition compared to both cluttered (p<.001) and control condition (p<.001), but no significant difference was found between cluttered and control condition (p=.11). No significant cortisol group by condition interaction effect was identified for scan rate (F(2,78)=.76, p=.47, η_p^2=.02).

Relative number of dwells at blocks

The HCG looked significantly more often at the blocks than the LCG (F(1, 39)=15.52, p<.001, η_p^2=.29). In addition, a significant effect of condition (F(2,78)=68.57, p<.001, η_p^2=.64) and significant cortisol group by condition interaction effect was identified (F(2,78)=11.38, p<0.001, η_p^2=.23). The HCG looked more often at the cluttered blocks (p<.001) and the large blocks (p=.03) compared to the LCG. However, within the HCG and LCG there were no significant differences between the relative number of times looking at the cluttered and large blocks (p=.07 and p=.11 respectively).

Relative number of dwells at ball

There was no significant difference between the HCG and LCG in the relative number of dwells at the ball (F(1, 39)=0.11, p=.75, η_p^2=.003). However, a significant effect of blocks (F(1.48, 57.61)=15.95, p<.001, η_p^2=.29) and cortisol group by condition interaction effect was identified (F(1.48, 57.61)=4.83, p=.02, η_p^2 =.11). The HCG looked significantly less often at the ball in the cluttered block condition compared to the LCG (p=.036) but no differences between groups were identified in the control (p=.18) and large block condition (p=.55). In addition, the HCG looked significantly more often at the ball in the control condition, compared to the cluttered (p<.001) and large block condition (p<.001) but no differences were identified between the cluttered and large block condition in the number of times looking at the ball (p=.33). The LCG looked significantly more often at the ball in the control condition compared to the large block condition (p=.03), but no differences were identified between other conditions on the relative number of times the ball was visually attended to (p>.05).

Relative number of dwells at target

There was no significant difference between the two cortisol groups in the relative number of dwells at the target ($F(1,39)=0.07$, $p=.79$, $\eta_p^2=.002$). However, a significant effect of condition ($F(1.66,64.98)=35.00$, $p<.001$, $\eta_p^2=.47$) and cortisol group by condition interaction effect was identified ($F(1.66,64.98)=5.93$, $p=.01$, $\eta_p^2=.13$) for relative number of dwells at the target. Post-hoc analysis identified that the HCG looked significantly more often at the target in the control condition ($p=.03$) compared to LCG, but no differences were identified in the cluttered ($p=.11$) and large block condition ($p=.49$). Both the HCG and LCG demonstrated a significant reduction in the number of times looking at the target when blocks were introduced. Relative number of dwells at the target were significantly greater in the control condition compared to cluttered (HCG: $p<.001$, LCG: $p=.047$) and large condition (HCG: $p<.001$, LCG: $p=.002$) but not between the large and cluttered block conditions ($p>.05$).

Relative number of dwells at gap

There was no significant difference between the HCG and LCG in the relative number of dwells at the gap in between the blocks ($F(1,39)=0.79$, $p=.38$, $\eta_p^2=.02$). As expected, a significant difference between control condition, where there was no gap, and cluttered and large block condition was identified ($F(2,78)=72.78$, $p<.001$, $\eta_p^2=.65$), however, no significant differences in frequency of looking at the gap were identified between cluttered and large block condition ($p>.05$) and no significant cortisol group by condition interaction effect was identified ($F(2,78)=.64$, $p=.53$, $\eta_p^2=.02$).

Relative number of dwells at green

The relative number of dwells at the green was not significantly different between the HCG and LCG ($F(1,39)=.021$, $p=.89$, $\eta_p^2=.00$). No significant effects for condition ($F(1.56, 60.65)=2.76$, $p=.08$, $\eta_p^2=.07$) or cortisol groups by condition interaction effect ($F(1.56,60.65)=.094$, $p=.86$, $\eta_p^2=.00$) were identified. Descriptive results of relative number of dwells are presented in table 6.4.

Table 6.4 Mean (M) and standard deviation (SD) of relative number of dwells in the HCG and LCG in the three different putting conditions.

	Large blocks		Cluttered Blocks		Control condition	
	M	SD	M	SD	M	SD
Nr of dwells blocks (%)						
HCG	9.61	5.55	11.38	5.46	0.00	0.00
LCG	5.83	5.15	4.11	3.47	0.00	0.00
Nr of dwells ball (%)						
HCG	14.63	3.29	13.93	3.95	19.40	3.20
LCG	15.25	3.31	16.19	2.44	17.39	6.01
Nr of dwells target (%)						
HCG	8.63	6.39	8.77	6.19	17.94	3.35
LCG	9.95	5.75	11.69	5.34	14.77	5.33
Nr of dwells gap (%)						
HCG	9.02	5.50	10.13	5.22	0.00	0.00
LCG	8.16	5.43	8.21	6.30	0.00	0.00
Nr of dwells green (%)						
HCG	2.34	4.42	0.98	1.42	2.47	6.11
LCG	1.90	2.84	1.06	1.74	2.44	2.63

Relative Dwell time

Dwell time at the blocks

The HCG looked significantly longer at the blocks than the LCG ($F(1,39)=13.31$, $p<.001$, $\eta_p^2=.25$), supporting the significant increase in the relative number of times the blocks were attended by the HCG in comparison to the LCG. In addition, a significant effect for condition ($F(2,78)=35.55$, $p<.001$, $\eta_p^2=.48$) and cortisol group by condition interaction effect was identified ($F(2,78)=8.48$, $p<0.001$, $\eta_p^2=.18$). Participants in the HCG looked for longer at the cluttered blocks ($p<.001$) and large blocks ($p=.04$) compared to the LCG. However, within the HCG and LCG there were no significant differences between the percentage of time looking at the cluttered and large blocks ($p=.07$ and $p=.38$ respectively).

Dwell time at the ball

There was no significant difference between HCG and LCG in the relative amount of time looking at the ball ($F(1,39)=1.50$, $p=.23$, $\eta_p^2=.04$). A significant effect of condition was found

F(1.71,66.66)=4.90, *p*=.014, η_p^2=.11) where participants looked significantly longer at ball in the control condition compared to cluttered block condition (*p* =.006) but not between the control condition compared to the large block condition (*p*=.083) or between the cluttered and large block condition (*p*=.17). No significant cortisol groups by condition interaction effect was identified (F(1.71,66.66)=0.11, *p*=.90, η_p^2=.00).

Dwell time at the target

There was no significant difference between the HCG and LCG in the relative amount of time looking at the target (F(1,39)=0.05, *p*=.83, η_p^2=.00). A significant effect of condition was identified (F(2,78)=18.99, *p*<.001, η_p^2=.33), where the relative amount of time looking at target was significantly higher in the control condition compared to cluttered (p =.002) and large block condition (*p*<.001). In the cluttered block condition participants looked significantly longer at the target compared to the large block condition (*p*=.014). No significant cortisol groups by condition interaction effect was identified (F(2,78)=1.70, *p*=.19, η_p^2=.04).

Dwell time at the gap

The relative time looking at the gap was not significantly different between the HCG and LCG (F(1,39)=.24, *p*=.63, η_p^2=.01). A significant difference between control condition, where there was no gap, and cluttered and large block was identified (F(2,78)=40.43, *p*<.001, η_p^2=.50), however, no difference in relative time looking at the gap was identified between cluttered and large blocks (*p*>.05). No significant cortisol groups by condition interaction effect was identified (F(2,78)=.28, *p*=.76, η_p^2=.01).

Dwell time at the green

The relative time looking at the green was not significantly different between the HCG and LCG (F(1,39)=.007, *p*=.93, η_p^2=.00). No significant effects for condition (F(1.71,66.66)=1.14, *p*=.32, η_p^2=.03) or cortisol groups by condition interaction effect (F(1.71,66.66)=.76, *p*=.47, η_p^2=.02) were identified.

Quiet eye period

The relative QE period was not significantly different between the HCG and LCG ($F(1, 39)=.42$, $p=.52$, $\eta_p^2=.01$). No significant effects for condition ($F(1.59,62.16)=2.61$, $p=.09$, $\eta_p^2=.063$) or cortisol groups by condition interaction effect ($F(1.59,62.16)=.74$, $p=.45$, $\eta_p^2=.02$) were identified. See table 6.5 for the descriptive results of relative dwell time.

Table 6.5 Mean (M) and standard deviation (SD) of relative dwell time in the HCG and LCG in the three different block conditions.

	Large blocks		Cluttered Blocks		Control condition	
	M	SD	M	SD	M	SD
Dwell time blocks (%)						
HCG	4.85	3.59	6.18	3.88	0.00	0.00
LCG	2.52	3.58	1.83	1.96	0.00	0.00
Dwell time ball (%)						
HCG	23.60	6.40	20.39	7.70	22.59	7.93
LCG	22.70	8.87	23.71	6.61	23.18	9.91
Dwell time target (%)						
HCG	6.77	5.28	8.17	6.04	12.68	4.60
LCG	6.89	4.79	9.08	6.21	10.73	5.73
Dwell time gap (%)						
HCG	5.03	3.70	4.75	3.53	0.00	0.00
LCG	4.18	3.89	4.52	4.70	0.00	0.00
Dwell time green (%)						
HCG	1.58	2.85	0.94	1.67	1.11	3.60
LCG	1.24	2.34	0.73	1.71	1.82	2.75
Quiet Eye (%)						
HCG	30.62	11.29	32.36	14.85	35.81	10.84
LCG	35.73	14.59	32.50	12.51	37.85	19.70

6.3.6 sAA grouping

To further explore the effect of SNS activation on performance, performance execution and visual search behaviour a grouping of participants into high and low sAA was conducted. Participants were categorised in a high sAA group when sAA concentration at -5 minutes was higher than consecutive time points (HAAG). Participants were grouped into a low sAA group (LAAG) when sAA concentration immediately after the trial and/or 20 minutes after the trial was higher than at -5 minutes. The sAA concentration of 17 participants in the HAAG, was not significantly different from the 24 participants in the LAAG ($F(1,39)=0.02$, $p=.89$, $\eta_p^2=.00$). There was no significant saliva collection time effect ($F(1.65,64.19)=.41$, $p=.63$, $\eta_p^2=.01$). A sAA group by saliva collection time interaction effect ($F(1.65,64.19)=19.72$, $p<.001$, $\eta_p^2=.336$) partially supported the identification of participants into distinct groups (i.e., HAAG and LAAG). There was a strong trend for sAA to be higher in the HAAG compared to the LAAG group ($p=.06$) before the trial (e.g., -5 minutes). In contrast, immediately after the trial, there was a trend for sAA to be higher in the LAAG compared to the HAAG ($p=.06$). These identified differences were not present 20 minutes after the trial ($p=.93$). In addition, sAA in the HAAG was significantly higher before the trial compared to immediately after ($p<.001$) and 20 minutes after ($p=.03$). The sAA concentration in the HAAG, immediately after the trial, was not significantly different from 20 minutes after the trial ($p=.17$). In contrast, the LAAG had significantly lower sAA levels before the trial in comparison to immediately after the trial ($p<.001$) and sAA immediately after the trial was significantly higher than 20 minutes after the trial ($p=.01$). sAA in the LAAG was not significantly different between samples collected before the trial compared to 20 minutes after the trial ($p=.11$). See figure 6.6.

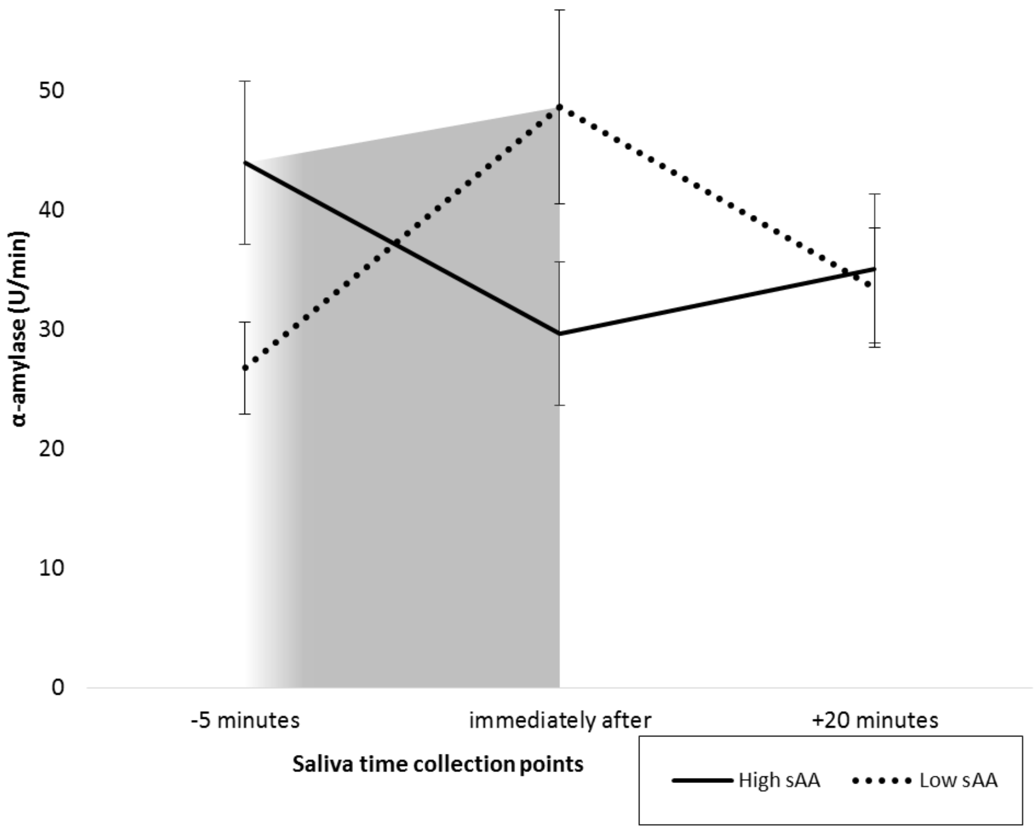

Figure 6.6 The sAA concentration in at the 3 time collection points for the low and high sAA group (M ± SE). Shaded area denotes period of golf putting task.

The identified groups of sAA were used to assess whether these groups demonstrated differences in the self-reported measures of anxiety, performance, performance execution and visual attention. The same variables and analysis were used as in the analysis of two different cortisol groups. The grouping of participants in a HAAG and LAAG did not reveal significant differences in self-reported measures, mean radial error or bivariate variable error of end ball location, performance execution variables and measures of visual search behaviour.

6.3.7 Cognitive anxiety grouping

As cognitive anxiety was significantly higher in the HCG group compared to the LCG an exploratory analysis was conducted to assess whether cognitive anxiety had an effect on the dependent variables of performance, performance execution and visual attention. Based on a median split of cognitive anxiety scores, 20 participants were group into a high cognitive group and 21 into a low cognitive anxiety group. There were no significant differences between the high and low cognitive anxiety groups in the dependent variables of performance, performance execution and visual search behaviour described earlier.

6.4 Discussion

Activation of the HPA-axis has been shown to be associated with changes in the direction of visual attention as well as performance in fine motor skills (Hatfield et al., 2013; Shields et al., 2015). The present study examined whether inter-individual differences in SNS and HPA-axis reactivity influences performance, performance execution and visual search behaviour in a golf putting task with task-relevant and irrelevant stimuli. Following a pressure manipulation with self-presentation and performance-contingent financial stimuli, participants were divided into two distinct groups, with high and low cortisol levels. According to the BPSM (Blascovich & Mendes, 2000; Dienstbier, 1989), it is postulated that this grouping, based on HPA-axis reactivity, reflects a more threatened state in the HCG in comparison to the LCG. The HCG performed significantly worse than participants in the LCG, as evidenced through a significantly greater mean radial error of the end ball location. Although the HCG executed the downswing significantly quicker, key kinematic variables related to the direction and length of the golf putt (i.e., impact angle, impact velocity and backswing length) and variability in these variables were not significantly different between the cortisol groups. The analysis of visual search behaviour identified that the HCG looked significantly more often and for longer at the task-irrelevant information on the putting green compared to the LCG. In contrast, no significant differences in performance, performance execution and visual search behaviour were identified when participants were categorised into groups of high and low SNS reactivity.

Consistent with the findings of chapter 4 of this thesis it was identified that HPA-axis reactivity show great inter-individual variety. Categorising participants into high and low cortisol groups, according to 1.5nmol/l change in cortisol (Miller et al., 2013), created distinct groups, where participants in the HCG had significantly higher cortisol levels than those in the LCG on commencing the golf putting task (2.5 nmol/l, d = 0.75). These findings were supported by significantly higher cognitive anxiety levels before the trial in the HCG compared to the LCG.

The identified cognitive anxiety levels in the HCG (17.0 ± 5.4) are slightly lower than those reported in chapter 4 of this thesis (18.1 ± 5.3) but comparable to chapter 5 of this thesis (17.3 ± 4.8) and to values reported in high pressure conditions in golf putting studies using self-presentation and financial incentives (Chamberlain & Hale, 2007; Mullen et al., 2005). Based on this it can be concluded that half of the participants (the HCG) experienced the stress manipulation as more stressful than the LCG. Of particular interest is that cortisol concentration in the HCG was significantly higher immediately before and after the trial, in comparison to 20 minutes after the trial. This supports previous work on the presence of an anticipatory cortisol response in psychosocial laboratory stress manipulations (Engert et al., 2013) as well as in real sport competitions (experimental chapter 2). Although the absolute levels of cortisol reported in the current experiment (HCG: 5.5 ± 1.1 nmol/l) are comparable to the group average in chapter 4 (5.9 ± 0.9 nmol/l) and Engert et al. (2013), they are below the maximum values of the responder group in chapter 4, studies using the CPT (Lautenbach, 2017) and TSST (Mascret et al., 2016). Both Lautenbach (2017) and Mascret et al. (2016) identified these changes following the stress manipulation, where both studies reported relative high baseline levels of cortisol. Indeed, the difference in cortisol between the HCG and LCG (2.5 nmol/l) is comparable to the magnitude of change in cortisol as reported in previous studies (Dickerson & Kemeny, 2004; Hatfield et al., 2013; Lautenbach, 2017; Mascret et al., 2016).

The current study is one of the first studies to provide evidence for the influence of HPA-axis activation on the underlying processes of sport performance. Studies using psychological stressors independently of task completion generally do not identify that cortisol affects motor skills performance (Lautenbach, 2017; Mascret et al., 2016). The current study, with self-presentation and motivational stimuli related to task performance, identified that the mean radial error of the end ball location was significantly larger and thus further away from the target in the HCG compared to the LCG, highlighting a reduction of putting accuracy with high cortisol. It was expected that these changes in accuracy would be reflected in significant changes in the key performance variables of executing the golf putt. However, only a significantly shorter downswing time in the HCG was identified, where other performance execution variables were not significantly different between the HCG and LCG. These findings contradict the results of Hatfield et al. (2013) where performance outcome in a shooting task was maintained whilst the fluency of motor behaviour decreased under high pressure conditions with increased cortisol, compared to a low pressure condition with low cortisol. However, Hatfield et al. (2013) specifically examined jerk (i.e., the rate change of acceleration), a relevant performance indicator of rifle shooting, whilst the current study examined the key performance indicators related to direction and speed of the golf ball. The non-significant differences in performance execution variables can be partially explained by a non-significant difference in the variable error of end ball location between the HCG and LCG. In other words, the HCG were consistently less accurate than the LCG. A variable such as impact velocity is not able support this result as some participants in the HCG might have consistently hit the ball with lower impact velocity where other participants might have consistently hit the ball with higher impact velocity. More importantly, the identified performance execution measures in the current study are comparable to those reported in chapter 5 of this thesis. For example, DS time (chapter 5: 0.28s, chapter 6: 0.27s) and impact velocity in forward direction (chapter 5: 1.46 $m.s^{-1}$, chapter 6: 1.51 $m.s^{-1}$) are comparable between chapters, suggesting that the novice participants executed the task similarly. A more plausible explanation for the differences in performance between the HCG and LCG can come from the differences in visual search behaviour. The HCG demonstrated to be more distracted by the task-irrelevant information in the form of blocks on the putting green. Participants in the HCG looked significantly more often and for longer at these blocks than the LCG, irrespective of trial time. This change in visual search behaviour in the HCG supports previous findings of changes in visual search behaviour in high compared to low anxiety conditions (Janelle, 2002). Moreover, it enhances the understanding that individual differences in stress reactivity influences visual search behaviour. Where other studies predominantly examine the changes in visual search behaviour to task-relevant information (Causer et al., 2011), the current study support findings from the psychology domain on the role of anxiety and stress on visual attention to task-irrelevant information. The increase in attending to task-irrelevant information in the HCG suggests that resistance to distractor interference (Friedman & Miyake, 2004) was reduced, reflecting an increased influence of the stimulus-driven attentional system in the HCG. This contradicts the conclusion from a meta-analysis by Shields et al. (2015) that cortisol improves inhibition. However, Shields conclusion was based on studies using exogenous cortisol administration where administration of a typical dose of 40mg hydrocortisone, results in saliva cortisol concentration of around 100 nmol/l (Putman & Berling, 2011). These concentrations of salivary cortisol are normally not reached in emotional stress manipulation (Dickerson & Kemeny, 2004). Moreover, studies using exogenous cortisol administration typically assess cognitive functioning during emotional neutral tasks where there is evidence that stress-induced cortisol affects cognitive functioning differently than exogenous cortisol administration (Qin et al., 2009; Weckesser, Alexander, Kirschbaum, Mennigen, & Miller, 2016). Indeed, Weckesser et al. (2016) identified that exogenous cortisol administration increased dual-task performance whereas stress induced cortisol (via the TSST) negatively affected dual-task performance, postulating that acute stress affects cognitive functioning differentially from exogenous cortisol probably due to combined effects of changes in SNS and HPA-axis activation (Qin et al., 2009). The findings in the current experiment that the HCG increased their attention towards task-irrelevant information supports the conclusion from Shields, Sazma and Yonelinas (2016) who identified that acute stress and increased cortisol concentration negatively affects cognitive inhibition (e.g., resistance to distractor interference and interference control) as opposed to response inhibition. However, as the current study identified a significant higher cognitive anxiety levels in the HCG, it remains unclear whether cortisol or the experienced negative emotions influenced these changes in visual search behaviour. Whilst the HCG visually attended more to task-irrelevant information, this did not result in significant changes (i.e., reduction) in attending to task-relevant information. The expected changes in attending to task-relevant information are reflected in a reduction in the length and frequency of attending to multiple task-relevant AOIs (i.e., ball and target). Indeed, the frequency of attending to both the ball and target were lower in the HCG in the trials with blocks on the putting green, albeit not significantly different from the LCG (see table 6.4). In addition, both the length of the QE and relative time attending to target were lower in the HCG compared to the LCG, however, not significantly different (see table 6.5).

Both visual search behaviour as well as performance were significantly affected by the different block conditions. Task constraints in the two block condition were similar (i.e., the gap created was constant), however, the saliency of the blocks was distinct (see figure 6.1 and 6.2). The large block condition negatively affected performance accuracy in comparison to the cluttered and control condition which was supported by both a significant shorter downswing time and higher impact velocity in the large block condition compared to cluttered and control condition. Changes in visual search behaviour explained these performance decrements, as the target and ball were significantly shorter and less often attended to in the large block condition compared to the control condition. These findings support the evidence of coupling of visual attention to motor skill execution (M. F. Land, 2009) and supports both the success of the saliency manipulation as well as the task-irrelevancy of these stimuli.

6.4.1 Limitations

The grouping of participants based on cortisol profiles of reduced or increased cortisol reactivity, created two distinct groups with different cortisol levels before the trial. The high group started the trial with significantly higher cortisol levels than the low group. Immediately after the trial both groups did not have significantly different cortisol levels. This implies that the magnitude of the difference in cortisol between the groups reduced during the trial. An increased frequency of saliva collection, with the collection of a saliva sample halfway the golf putting trial, can clarify whether cortisol differences between groups existed during the trial. In addition, the study identified relatively low absolute levels of cortisol. These were partially pre-determined due to circadian variation in cortisol, where the lowest levels of cortisol are recorded in the afternoon and late evening, at the time of day this experiment was completed (Hucklebridge et al., 1998). Moreover, the low absolute cortisol concentration has affected the recording of baseline samples of cortisol on a resting day. The inclusion of resting cortisol samples in the current study aimed to assess cortisol reactivity more accurately. In contrast to the expectation, baseline cortisol levels of a large proportion of participants was higher in comparison to the samples collected around the stress manipulation. Day-to-day variation in cortisol are expected due to the experience of stressors outside the control of the experimenter (e.g., participants might experience daily stressors that activate cortisol). Hence, particularly saliva sampling in the afternoon is affected by this as both the threshold to increase cortisol is lower and it is more likely that participants have experienced stressors during the day. In addition to these factors, the participant population (e.g., undergraduate university students) might have experienced more stress around the collection of baseline samples than during the golf putting trial. Data collection of the study took place in final semester of the academic year, where baseline samples were collected later in semester than the golf putting trial (e.g., the golf putting trial was completed before the baseline samples were collected). It is plausible that a proportion of the participants experienced more academic stress at the time of collecting the baseline samples, which increases general cortisol concentration (Murphy, Denis, Ward, & Tartar, 2010) .

6.4.2 Conclusion

The current study provides evidence for the influence of cortisol on performance and visual attention in perceptual motor skills. The prediction that participants with high cortisol would demonstrate greater inhibition of task-irrelevant stimuli was not supported. In contrast, participants with high cortisol demonstrated to become more distracted by the task-irrelevant stimuli, in addition, the HCG performed worse than the LCG. These findings can be explained from the perspective of cognitive functioning where cortisol negatively affects resistance to distractor interference resulting in greater influence of stimulus-driven attentional control system. Concurrently, the finding of distinct differences in performance and visual search behaviour in relation to HPA-axis reactivity supports the predictions of the BPSM, in that greater HPA-axis reactivity, an indicator of a threatened state, negatively affects performance and visual search behaviour in high pressure conditions.

Chapter 7: General Discussion

The aim of this thesis was to examine the influence of anxiety and the endocrine response on visual attention and performance execution in perceptual-motor skills. In order to examine the aforementioned, it was first necessary to identify the magnitude of the endocrine response in real sport competition and then validate an approach to elicit a similar endocrine response in a laboratory environment. Based on the successful laboratory validation of the pressure manipulation, additional studies used this manipulation to investigate the effects of anxiety and the inter-individual differences in endocrine reactivity on visual search behaviour and performance execution in a golf putting task. This general discussion summaries the key findings of the studies. The discussion then considers the theoretical implications, limitations and future directions for the field of research on stress, anxiety and sport performance based on the evidence of this thesis.

7.1 Summary of findings

Where there is extensive evidence for the presence of an emotional response (e.g., development of anxiety) in anticipation to sport competition (Craft et al., 2003; Hanton et al., 2004; Woodman & Hardy, 2003), there is currently limited evidence investigating the moderators and extent of the endocrine response in anticipation to sport competition. The role and influence of cortisol, a measure of HPA-axis activity, on sport performance is typically examined in naturalistic environments and includes the examination of post-competition measures of cortisol (Casto & Edwards, 2016; Salvador, 2005). However, post-competition measures of cortisol are likely to be influenced by the intensity of the exercise (Jacks et al., 2002; Kudielka et al., 2009). These post-competition measures of cortisol might not be an accurate reflection of HPA-axis reactivity in response to psychological stress (Henry, 1992). Therefore, the aim of chapter 2 was to identify the magnitude of the anticipatory cortisol response in real sport competition and to investigate moderating variables on this cortisol response. Although an experimental study could highlight the magnitude of the anticipatory cortisol response, it is more challenging to examine several moderating variables. Hence, within chapter 2 a systematic review with meta-analysis was conducted where the results of experimental studies on the anticipatory cortisol response were summarised and aggregated. From 25 identified studies with 27 effect sizes it was concluded that cortisol is significantly increased in athletes anticipating to compete in real sport competitions (g=0.85. $p<.001$). The analysis of moderating variables identified that males, in contrast to females, experience a significant anticipatory cortisol response. In addition, the anticipatory cortisol response was significantly higher when assessed closer to the start of the competition and was higher in athletes competing at lower performance standards. Although these findings provide support that the emotional response in anticipation to sport competition is accompanied by a distinctive anticipatory cortisol response, it was identified that there was large heterogeneity between studies. This variation could not be fully explained through the analysis of moderating variables and highlights the large variability in HPA-axis reactivity in response to stressful situations.

The examination of the influence of anxiety on the underlying processes of perceptual-motor skill performance is commonly conducted in laboratory environments where a simulation of a competitive sport environment is recreated. The adopted pressure manipulations significantly increase anxiety levels compared to neutral conditions, but are below those reported in real sport competitions, challenging ecological validity of using these pressure manipulations (Chamberlain & Hale, 2007; Jones, 1995; Mullen et al., 2005; Williams et al., 2001). Indeed, Mesango et al. (2011) compared various self-presentation and performance contingent motivational stimuli to identify that the combination of self-presentation and performance contingent motivational stimuli, creates the strongest emotional stress response. However, there are currently limited studies that have examined the associated endocrine response to these pressure stimuli. Although experiencing psychosocial stressors can influence the endocrine response (Dickerson & Kemeny, 2004), both HPA-axis and SNS reactivity share low covariance with self-reported psychological responses (Engert et al., 2013; Gaab et al., 2005; Kudielka et al., 2009; Nater et al., 2005; van Stegeren et al., 2008) due to inter-individual differences in appraisal of the stressors (Gaab et al., 2005) and factors such as gender, genetic predisposition, physical fitness, habituation to stress and early life experiences (Boyce & Ellis, 2005; Henry, 1992; Kudielka et al., 2009; Rimmele et al., 2007). Additionally, HPA-axis and SNS reactivity form the basis of BPSM ((Blascovich & Mendes, 2000; Dienstbier, 1989) where SNS reactivity reflects task engagement and inter-individual differences in HPA-axis reactivity indicating challenged or threatened states. The evidence from chapter 2, of the presence of a significant anticipatory cortisol response in real sport competitions, albeit with large inter-individual differences, provided an initial indication of variance in HPA-axis reactivity between athletes. However, studies examining the effects of both anxiety and challenged and threat states on sport performance make use of laboratory environments. Hence, it is of interest to examine whether the endocrine response in a real sport competition is comparable to that in a laboratory pressure manipulation. Therefore, the aim of chapter 4 was to examine whether a pressure manipulation with self-presentation and performance contingent monetary rewards would influence the endocrine response. To investigate this, 28 males completed golf putts in a high pressure condition where putting performance was socially evaluated via an audience, performance comparison, a video camera and monetary rewards. SNS (i.e., sAA) and HPA-axis activation (i.e., cortisol) was measured in each participant by collecting 5 saliva samples around the pressure manipulation. Concurrently participants completed self-reported measures of stress, arousal and anxiety. The assessment of salivary cortisol revealed large inter-individual differences in HPA-axis reactivity, confirming previous findings in the general psychology domain. Half of the participants, categorised as responders, had a significant increase in cortisol in the high pressure stress manipulation. In contrast, non-responders, did not demonstrate this reactivity. The magnitude change in cortisol in the responder group (d= 1.04) was comparable to the identified effect size in the meta-analysis conducted in chapter 2. These between group differences in HPA-axis reactivity were not evident in SNS reactivity as both responders and non-responder showed a similar, and non-significantly different, profile in sAA reactivity around the pressure manipulation (see figure 4.3). This confirms previous findings that SNS reactivity in response to stress is more uniform than HPA-axis reactivity (Boyce & Ellis, 2005; Henry, 1992; Kivlighan & Granger, 2006). Concurrently, the evidence of increased SNS reactivity around the pressure manipulation indicates high levels of task engagement. In contrast, the differences in cortisol reactivity between responders and non-responders provides an indication that participants experienced the pressure manipulation differently. According to Dienstbier (1989) the combined effects of SNS and HPA-axis reactivity would indicate that the responder group experienced a more threatened state whereas the non-responders experience a challenged state. Although self-reported measures of anxiety were comparable to previous studies (Chamberlain & Hale, 2007; Mullen et al., 2005), it was of interest that the self-reported measures of anxiety showed weak correlations with both absolute levels of cortisol and sAA as well as reactivity (i.e., magnitude change) in sAA and cortisol. This finding provides an interesting insight in the differences between the emotional response and endocrine response to this pressure manipulation, suggesting that the emotional response and endocrine response are distinct. With the evidence that HPA-axis reactivity affects both stimulus-driven and goal-directed visual attention (Schwabe et al., 2013; Shields et al., 2015; Taylor et al., 2011) as well as the coordination of motor skill execution (Hatfield et al., 2013; Metz et al., 2005) the two additional studies in this thesis examined the role of anxiety and the endocrine response on the underlying processes (e.g., visual search behaviour and kinematic execution) of perceptual-motor skills.

The effects of anxiety on performance, movement execution and visual attention in perceptual-motor skills are typically examined by comparing these processes involved in goal-directed action under a high pressure and low pressure condition. However, these underlying processes (e.g., movement execution and visual search behaviour) of perceptual-motor skill performance are not consistently examined. Studies predominantly focus on either the effects of anxiety on performance and movement execution or the goal-directed and stimulus-driven attentional systems. Within chapter 5 an interdisciplinary approach was adopted, according to the suggestions of Nieuwenhuys and Oudejans (2012), where the effects of anxiety at an attentional level (e.g., visual search behaviour) as well as a behavioural level (e.g., movement execution) were examined. This approach allowed for the examination of whether anxiety affects the selection of information and/or movement execution. The effects of anxiety on visual attention were investigate via the theoretical predictions of ACT (Eysenck et al., 2007). ACT postulates that anxiety affects visual attention via a reduced capacity to inhibit task-irrelevant stimuli and longer response latencies disengaging from these stimuli (Derakshan et al., 2009; Eysenck & Derakshan, 2011). Hence, under anxiety conditions visual search behaviour is characterised by a shift in attention away from task-relevant information to task-irrelevant information (Wilson, 2008). Current studies in the sport domain mainly investigate whether anxiety affects visual search behaviour towards task-relevant information and postulate that these changes in the goal-directed attentional system are due to the effects of anxiety on overt and/or covert attention towards task-irrelevant information (Causer et al., 2011; Nibbeling et al., 2012). Hence, within chapter 5, the influence of anxiety on resistance to distractor interference (Friedman & Miyake, 2004) was examined, where visual search behaviour towards both task-relevant and irrelevant information was assessed. Within chapter 5 it was hypothesised that changes in the balance between the goal-directed and stimulus-driven attentional systems under anxiety conditions would affect the execution of the perceptual-motor skill. Although studies assess the influence of anxiety on performance execution in golf putting, studies predominantly examine changes in fluency of movement (Cooke et al., 2010; Mullen & Hardy, 2000; Tanaka & Sekiya, 2010). As the key performance indicators of the golf putt are club head angle at ball impact and impact velocity (Delay et al., 1997; Karlsen et al., 2008), it was these variables, and the variability in these variables, that were used to analyse movement execution. Therefore, the aim of chapter 5 was to test the effects of anxiety on performance, movement execution and visual attention towards both task-relevant and irrelevant information. A golf putting task with physical blocks (e.g., task-irrelevant stimuli) positioned on the putting green was developed where novice participants completed golf putts under both a high and low pressure condition. The pressure manipulation resulted in a significant increase in self-reported cognitive and somatic state anxiety in the high pressure condition, comparable to those reported in chapter 4. Concurrently, the results identified that performance accuracy (i.e., MRE) significantly increased in the high pressure condition, which was reflected in significant changes in movement execution and visual attention. Under high pressure a significant reduction in visual attention towards task-irrelevant information (i.e., blocks) and variability in the impact angle of the club head were identified. A mediation analysis identified that this reduction in variability of club head angle at ball impact explained the significant increase in performance accuracy (e.g., MRE of the end ball location) in the high pressure condition. Whilst these results contradict the suggested negative effects of anxiety on sport performance, they provide partial support for the prediction of ACT in the sport domain. Performance accuracy in this perceptual-motor task was improved (e.g., task effectiveness) whilst the changes in visual search behaviour identified an increased resistance to distractor interference inhibition and reduced influence of the stimulus-driven attentional system. These findings provide support for the notion that increased psychological activation results in a decrease in attention towards neutral environmental stimuli that are not relevant for task completion, in comparison to emotional or threatening information (Chajut & Algom, 2003; Sørensen & Barratt, 2014). Although the results provided an interesting insight into the effects of anxiety on attentional process and movement execution, they concomitantly raised the question what the role of inter-individual differences in endocrine reactivity were.

Chapter 4 identified that the high pressure condition used in this thesis resulted in distinct reactivity of the HPA-axis, as identified via salivary cortisol. In contrast to SNS-activation (i.e., sAA), HPA-axis reactivity highlighted that some participants reacted strongly to high pressure manipulation, indicating a more threatened state, where others did not demonstrate an increase in cortisol, an indication of a challenged state. These changes in cortisol levels are suggested to influence movement execution negatively through cortico-cortical input to the cerebellum and motor cortex (Hatfield et al., 2013). In contrast, moderate levels of exogenous cortisol administration enhances pre-potent motor response and resistance to distractor interference inhibition through the direct influence of cortisol on the PFC (Schwabe et al., 2013;

Shields et al., 2015; Taylor et al., 2011). Hence, it was of interest to investigate the influence of endocrine reactivity on movement execution and the stimulus-driven and goal-directed attentional systems in a perceptual-motor skill. With the inter-individual difference in cortisol reactivity identified in chapter 4, an exploratory research design was adopted with the aim to identify the influence of endocrine reactivity on performance, movement execution and visual attention towards task-relevant and irrelevant information. Forty one participants were exposed to a high pressure manipulation with the aim to separate participants into a high and low cortisol category (Ioannou et al., 2016; Quaedflieg et al., 2015; Steinbeis et al., 2015). Although clear differences in cortisol reactivity were identified in chapter 4, the collection of baseline samples, on a separate day, of both cortisol and sAA were included to provide a more accurate measure of SNS and HPA-axis reactivity. The baseline samples of cortisol, collected on a resting day, demonstrated great variability and were excluded from the analysis. Therefore, a cortisol grouping based on a 1.5nmol/l change in cortisol between the 3 sampling points was used (Miller et al., 2013). This categorised 22 participants in a high cortisol group (HCG) and 19 participants in a low cortisol group (LCG). The HCG had significantly higher cortisol levels on commencing the golf putting task in comparison to the LCG (p=.004, d=0.75), but not at other time points. These two different cortisol groups did not demonstrate significant differences in their SNS activation, therefore indicating that the HCG most likely experienced a threatened state in contrast to a challenged state in the LCG, supporting the findings of chapter 4 and highlighting that SNS activation is more uniform than HPA-axis activation (Boyce & Ellis, 2005; Henry, 1992; Kivlighan & Granger, 2006). A comparison in putting accuracy (i.e., MRE) identified that the HCG performed significantly less accurate than the LCG. Although the HCG had a significantly shorter downswing time, key putting kinematic performance indicators such as the variability in club head angle or velocity at impact were not significantly different between the HCG and LCG and could not explain differences in performance accuracy. In contrast, changes in performance accuracy were supported by changes in visual search behaviour. The HCG looked significantly more often and for longer at both the large blocks and cluttered blocks on the putting green. These changes in visual attention highlight a stronger influence of the stimulus-driven attentional system in the HCG than the LCG. More specifically, it supports the suggestion that specifically the inhibition function “resistance to distractor interference” was negatively affected by cortisol. This negative effect on resistance to distractor interference contradicts studies using exogenous cortisol administration (Shields et al., 2015). However, using exogenous cortisol administration results in abnormally high levels of cortisol and these studies typically assess inhibition functions under neutral emotional conditions. In contrast, studies using acute stress to activate the HPA-axis tend to identify that cortisol negatively affects inhibition functions (Shields et al., 2016). Although the findings of the current study provide support that overt visual attention was more directed towards task-irrelevant information it should be acknowledged that the HCG also demonstrated significant higher levels of cognitive anxiety compared to the LCG. This would suggest that in addition to the higher cortisol levels, the HCG experienced an emotional state characterised by more worries indicative of experiencing the task as more threatening. This corroborates ACT as anxious thoughts are cognitive resource intensive and results in a reduction in inhibition of threatening stimuli and interpretation of salient stimuli as more threatening (Deraskhan et al., 2009). The increased frequency and length attending to the task-irrelevant blocks provides evidence for this. However, a reanalysis of the results by grouping participants into high and low levels of cognitive anxiety did not identify significant differences in visual attention towards task-relevant and irrelevant information. Hence, it seems more plausible that increase influence of the stimulus-driven attentional system in the HCG was the results of cortisol reducing resistance to distractor interference.

7.2 Strengths, limitations and future directions

The strengths of the current thesis are related to the interdisciplinary approach to the examination of stress and anxiety on the underlying processes of performance in perceptual-motor skills. The experimental studies in this thesis were one of the first to combine both measures of visual attention (e.g., visual search behaviour) as well as key kinematic variables related to the execution of the golf putt, to examine the underlying processes of performance under pressure. In addition, the examination of the biological stress response, with the identified inter-individual differences in stress reactivity, provides an interesting insight that participants react differently to commonly used stressors in laboratory settings. These differences in reactivity related to distinct differences in the direction of visual attention and performance in the execution of these skills. The current study was one of the first to examine sAA and cortisol reactivity to commonly used stressors adopted in the sport science and sport psychology domain. However, endocrine reactivity to these stressors was lower than reported in studies in the general psychological domain using psychosocial stressors. This warrants an important limitation regarding the adopted, and generally used, stress manipulation. The self-presentation stimuli related to the evaluation of perceptual-motor skill performance (e.g., via a video camera, through performance comparison or an audience) seem to influence HPA-axis less than psychosocial stressors used in the psychology domain (e.g., TSST). The TSST relies on social evaluative components created by the presence and behaviour of an audience. The presence of the audience during the completion of a mental arithmetic task and delivery of a speech is suggested to influence self-evaluative states related to potential failure (Dickerson & Kemeny, 2004). These components specifically address ego-involvement in task completion. In contrast, the evaluation of sport performance in front of an audience might not achieve a comparable level of ego-involvement as delivering a speech. In other words, participants might not have felt that their performance in the putting task was a reflection of their self. This effect might be exaggerated due to the use of novice participants, who probably held low expectations of being successful in the task. Whilst the financial rewards offered to the top performers served as an incentive to do well, a setting with losing money for poor performance would affect ego involvement more. Although the TSST, or components of the TSST, can be successfully used to increase cortisol during perceptual motor skills execution, there is evidence that the separation of the psychosocial stressors from the performance task is not effective to examine the effects of endocrine reactivity on sport performance in experimental settings (Lautenbach et al., 2014; Lautenbach, 2017; Mascret et al., 2016). Hence it is recommended to further explore the effects of pressure manipulations in the sport domain on the endocrine response in a similar realm as Mesango et al. (2011) examined the effects of different pressure manipulations on the emotional stress response.

The interdisciplinary approach in the thesis, where both measures of visual search behaviour as well as movement execution variables were examined, generally supported the link between the effective use of visual information to guide performance execution (M. F. Land, 2009). Changes in visual attention under pressure or with greater endocrine reactivity were reflected in changes in performance execution and ultimately performance accuracy. Previous studies, predominantly examining the application of ACT in sport, highlighted that anxiety and stress result in an imbalance between the goal-directed attentional and stimulus-driven attentional system. However, the use of measures of visual search behaviour typically operationalise the effects of anxiety in changes in attending to task-relevant information (e.g., the goal-directed attentional system) whilst implying that these changes are due to a greater influence of the stimulus-driven attentional control system. The studies in this thesis postulated that the changes in goal-directed visual attention under anxiety conditions should be reflected in attending more to information in the environment that is not directly task-relevant. Whilst this approach examined the fundamental of ACT that inhibition of task-irrelevant external stimuli is reduced by anxiety, it did not preclude the influence of internal distracting stimuli (e.g., worrisome thoughts). The choice of including external stimuli with reduced task-relevance partially originated from authors reporting that the changes in visual attention to task-relevant information were due to "increased distraction by task-irrelevant information", however, not specifying these. In addition, studies in the psychology and sport science domains, regularly use stimuli that require participants to respond to these irrelevant stimuli (Derakshan et al., 2009; Janelle et al., 1999) or that these stimuli played an important role in the task (Wilson et al., 2009). A pure assessment of whether anxiety affects inhibition of environmental information in sport should come from investigating whether resistance to distractor interference is affected by anxiety. The included blocks in the experimental design in this thesis were postulated to be these sources of task-irrelevant information, however to what extent were these blocks task-irrelevant? Firstly, the blocks were positioned on the lateral sides of the green, in between the task-relevant stimuli hole/target and ball. If the blocks, or the created gap by the blocks, were deemed task-relevant by the participants, an increase in attending to these blocks or gap should be evidenced by changes in visual search behaviour irrespective of anxiety conditions or endocrine reactivity. In general, the blocks were attended to only a small amount of time: the ball and hole/target were still the key sources in information attended to. In addition, both in the low and high anxiety comparison, as well as in the HCG and LCG comparison it was clear that these conditions created uniform differences in attention to these blocks. If the blocks were deemed task-relevant, changes in attending to these blocks were not expected. Based on these arguments and findings it can be concluded that the blocks on the putting green were more task-irrelevant than relevant and therefore support the value of this paradigm in examining the influence of anxiety and stress on the inhibition of task-irrelevant information. Although evidence from visual search behaviour provides support for the task-irrelevancy of the blocks, a retrospective assessment of the perception and role of the blocks could clarify this further. As highlighted by Nieuwenhuys and Oudejans (2012), individuals perceive environmental information differently when anxious. For example, perceived reaching ability is reduced when high on a climbing wall compared to low on a climbing wall (Pijpers, Oudejans, Bakker, & Beek, 2006) and participants characterised as "chokers", perceive the hole to be smaller in a golf putting task under high pressure (Gray & Canal Bruland, 2015). Moreover, it is of particular interest to examine what the role of endocrine reactivity is in the perception of information, particularly as individuals with high cortisol attended significantly more to the blocks. As this change in cortisol coincided with an increase in cognitive anxiety it was not possible to separate whether cortisol or the emotional response affected visual attention. Although studies with exogenous cortisol administration create abnormally high levels of cortisol, it would be of interest to examine how lower dosages of hydrocortisone administration would affect visual attention and movement execution. Particularly within a randomised control design it would be possible to compare and separate the emotional response, in a manipulation with self-presentation performance contingent financial stimuli, from the influence of cortisol via exogenous administration.

7.3 Integrated conclusion

Within this thesis an examination of the role of stress and anxiety on the underlying processes of performance in perceptual-motor skills were examined. The systematic review with meta-analysis (chapter 2) identified a significant anticipatory cortisol response in athletes before participating in sport competition. However, large heterogeneity in the anticipatory cortisol response was identified. Although some of this variance could be explained through moderator analysis (e.g., males, in contrast to females, demonstrated a significant anticipatory cortisol response) the findings suggest that HPA-axis reactivity in athletes has great inter-individual variability. Support for the validity of a laboratory stress manipulation, with self-presentation and performance contingent motivation stimuli, came from a comparison of cortisol reactivity during the laboratory stress manipulation (chapter 4) and real sport competitions (chapter 2). Although the magnitude self-reported anxiety was comparable to previous reported findings, it was identified that cortisol, a measure of HPA-axis activity, showed great inter-individual differences in reactivity. Half of participants demonstrated a cortisol response, comparable in effect size, to that identified in anticipation to real sport competitions, suggesting validity of the laboratory stress manipulation. In contrast, the other half of the participants did not demonstrate this cortisol response. This finding, combined with weak correlations between self-reported measures of anxiety and endocrine reactivity (e.g., cortisol and sAA) highlights two important considerations. Firstly, endocrine stress reactivity and the subjective psychological stress response were dissociated and therefore describe distinct features of the stress response to laboratory stress manipulations. Secondly, as increased HPA-axis reactivity is associated with experiencing greater social evaluative threat and uncontrollability (van den Bosch et al., 2009), it can be concluded that participants who demonstrated an increased cortisol response have experienced the task as more stressful and more threatening. Based on these findings the examination of the effects of anxiety (chapter 5) and inter-individual differences in stress reactivity (chapter 6) on performance, performance execution and visual search behaviour were separated. Within a repeated measures design (e.g., high-low pressure manipulation, chapter 5) it was identified that within the high pressure condition performance accuracy in a golf putting task improved, compared to a low pressure condition. Improvement in performance was explained by a significant reduction in the influence of the stimulus-driven attentional system (e.g., visual attention to task-irrelevant information reduced) combined with a reduction in variability in movement execution. In contrast, when participants were exposed to the high pressure condition to identify the role of inter-individual differences in cortisol reactivity, it was identified that high levels of cortisol, but not anxiety or SNS activation, negatively affected performance (chapter 6). Concurrently, high levels of cortisol reduced resistance to distractor interference inhibition (e.g., visual attention was directed more towards task-irrelevant information). These seemingly contradicting findings suggest that a certain level of psychological activation, motivation and challenge is beneficial for sport performance. Indeed, several studies identified that moderate levels of anxiety and challenged states, in contrast to threatened states, increase performance accuracy in golf putting (Chamberlain & Hale, 2007; Cooke et al., 2010; Moore et al., 2012; Moore et al., 2013; Mullen et al., 2005). However, when participants experience greater social evaluative threat and uncontrollability during the high pressure manipulation (e.g., as evidenced through increased HPA-axis reactivity) a reduction in performance accuracy and inhibition of task-irrelevant stimuli is evident.

References

Abedalhafiz, A., Altahayneh, Z., & Al-Haliq, M. (2010). Sources of stress and coping styles among student-athletes in jordan universities. *Procedia - Social and Behavioral Sciences, 5*, 1911-1917. doi:10.1016/j.sbspro.2010.07.387

Akinola, M., & Mendes, W. B. (2012). Stress-induced cortisol facilitates threat-related decision making among police officers. *Behavioral Neuroscience, 126*(1), 167-174. doi:10.1037/a0026657

Alix-Sy, D., Le Scanff, C., & Filaire, E. (2008). Psychophysiological responses in the pre-competition period in elite soccer players. *Journal of Sports Science & Medicine, 7*(4), 446-454.

Anshel, M. H., & Kaissidis, A. N. (1997). Coping style and situational appraisals as predictors of coping strategies following stressful events in sport as a function of gender and skill level. *British Journal of Psychology, 88*(2), 263-276. doi:10.1111/j.2044-8295.1997.tb02634.x

Anshel, M. H., Kang, M., & Miesner, M. (2009). The approach-avoidance framework for identifying athletes' coping style as a function of gender and race. *Scandinavian Journal of Psychology, 51*(4), 341-349. doi:10.1111/j.1467-9450.2009.00796.x

Arnsten, A. F. T., & Li, B. (2005). Neurobiology of executive functions: Catecholamine influences on prefrontal cortical functions. *Biological Psychiatry, 57*(11), 1377-1384. doi:10.1016/j.biopsych.2004.08.019

Balodis, I. M., Wynne-Edwards, K. E., & Olmstead, M. C. (2010). The other side of the curve: Examining the relationship between pre-stressor physiological responses and stress reactivity. *Psychoneuroendocrinology, 35*(9), 1363-1373. doi:10.1016/j.psyneuen.2010.03.011

Balsamo, M., Romanelli, R., Innamorati, M., Ciccarese, G., Carlucci, L., & Saggino, A. (2013). The state-trait anxiety inventory: Shadows and lights on its construct validity. *Journal of Psychopathology and Behavioral Assessment, 35*(4), 475-486. doi:10.1007/s10862-013-9354-5

Balthazar, C. H., Garcia, M. C., & Spadari-Bratfisch, R. C. (2012). Salivary concentrations of cortisol and testosterone and prediction of performance in a professional triathlon competition. *Stress, 15*(5), 495-502. doi:10.3109/10253890.2011.642033

Barnes, L. L. B., Harp, D., & Jung, W. S. (2002). Reliability generalization of scores on the spielberger state-trait anxiety inventory. *Educational and Psychological Measurement, 62*(4), 603-618. doi:10.1177/0013164402062004005

Baron, R. M., & Kenny, D. A. (1986). The moderator–mediator variable distinction in social psychological research: Conceptual, strategic, and statistical considerations. *Journal of Personality and Social Psychology, 51*(6), 1173-1182. doi:10.1037/0022-3514.51.6.1173

Bateup, H. S., Booth, A., Shirtcliff, E. A., & Granger, D. A. (2002). Testosterone, cortisol, and women's competition. *Evolution and Human Behavior, 23*(3), 181-192. doi:10.1016/S1090-5138(01)00100-3

Baumeister, R. F. (1984). Choking under pressure: Self-consciousness and paradoxical effects of incentives on skillful performance. *Journal of Personality and Social Psychology, 46*(3), 610-620. doi:10.1037/0022-3514.46.3.610

Baumeister, R. F., & Showers, C. J. (1986). A review of paradoxical performance effects: Choking under pressure in sports and mental tests. *European Journal of Social Psychology, 16*(4), 361-383. doi:10.1002/ejsp.2420160405

Behan, M., & Wilson, M. R. (2008). State anxiety and visual attention: The role of the quiet eye period in aiming to a far target. *Journal of Sports Sciences, 26*(2), 207-215. doi:10.1080/02640410701446919

Beilock, S. L., & Carr, T. H. (2001). On the fragility of skilled performance: What governs choking under pressure? *Journal of Experimental Psychology. General, 130*(4), 701-725. doi:10.1037/0096-3445.130.4.701

Beilock, S. L., & Gray, R. (2007). Why do athletes choke under pressure? *Handbook of sport psychology, 3rd ed* (pp. 425-444). Hoboken, NJ, US: John Wiley & Sons Inc.

Beltzer, E. K., Fortunato, C. K., Guaderrama, M. M., Peckins, M. K., Garramone, B. M., & Granger, D. A. (2010). Salivary flow and alpha-amylase: Collection technique, duration, and oral fluid type. *Physiology & Behavior, 101*(2), 289-296. doi:10.1016/j.physbeh.2010.05.016

Bishop, S. J. (2008). Neural mechanisms underlying selective attention to threat. *Annals of the New York Academy of Sciences, 1129*(1), 141-152. doi:10.1196/annals.1417.016

Bishop, S. J., Duncan, J., Brett, M., & Lawrence, A. D. (2004). Prefrontal cortical function and anxiety: Controlling attention to threat-related stimuli. *Nature Neuroscience, 7*(2), 184-188. doi:10.1038/nn1173

Bland, J. M., & Altman, D. G. (1997). Statistics notes: Cronbach's alpha. *Bmj, 314*(7080), 572. doi:10.1136/bmj.314.7080.572

Blascovich, J., & Mendes, W. B. (Eds.). (2000). *Challenge and threat appraisals: The role of affective cues.* Cambridge University Press.

Booth, A., Shelley, G., Mazur, A., Tharp, G., & Kittok, R. (1989). Testosterone, and winning and losing in human competition. *Hormones and Behavior, 23*(4), 556-571. doi:10.1016/0018-506X(89)90042-1

Borenstein, M., Hedges, L. V., Higgins, J. P., & Rothstein, H. R. (2011). *Introduction to meta-analysis* John Wiley & Sons.

Boyce, W. T., & Ellis, B. J. (2005). Biological sensitivity to context: I. an evolutionary–developmental theory of the origins and functions of stress reactivity. *Development and Psychopathology, 17*(2), 271-301. doi:10.1017/S0954579405050145

Brooks, G. A., Fahey, T. D., & White, T. P. (1996). *Exercise physiology: Human bioenergetics and its applications.* Mayfield publishing company.

Bruehl, H., Wolf, O. T., & Convit, A. (2009). A blunted cortisol awakening response and hippocampal atrophy in type 2 diabetes mellitus. *Psychoneuroendocrinology, 34*(6), 815-821. doi:10.1016/j.psyneuen.2008.12.010

Burton, D., & Naylor, S. (1997). Is anxiety really facilitative? reaction to the myth that cognitive anxiety always impairs sport performance. *Journal of Applied Sport Psychology, 9*(2), 295-302. doi:10.1080/10413209708406488

Buschman, T. J., & Miller, E. K. (2007). Top-down versus bottom-up control of attention in the prefrontal and posterior parietal cortices. *Science, 315*(5820), 1860-1862. doi:10.1126/science.1138071

Cacioppo, J. T., Malarkey, W. B., Kiecolt-Glaser, J. K., Uchino, B. N., Sgoutas-Emch, S. A., Sheridan, J. F., . . . Glaser, R. (1995). Heterogeneity in neuroendocrine and immune responses to brief Psychological Stressors as a function of autonomic cardiac activation. *Psychosomatic Medicine, 57*(2), 154. doi:10.1097/00006842-199503000-00008

Carré, J., Muir, C., Belanger, J., & Putnam, S. K. (2006). Pre-competition hormonal and psychological levels of elite hockey players: Relationship to the 'home advantage'. *Physiology & Behavior, 89*(3), 392-398. doi:10.1016/j.physbeh.2006.07.011

Casto, K. V., & Edwards, D. A. (2016). Testosterone, cortisol, and human competition. *Hormones and Behavior, 82*(Supplement C), 21-37. doi:10.1016/j.yhbeh.2016.04.004

Causer, J., Holmes, P. S., Smith, N. C., & Williams, M. A. (2011). Anxiety, movement kinematics, and visual attention in elite-level performers. *Emotion, 11*(3), 595-602. doi:10.1037/a0023225

Chajut, E., & Algom, D. (2003). Selective attention improves under stress: Implications for theories of social cognition. *Journal of Personality and Social Psychology, 85*(2), 231-248. doi:10.1037/0022-3514.85.2.231

Chamberlain, S. T., & Hale, B. D. (2007). Competitive state anxiety and self-confidence: Intensity and direction as relative predictors of performance on a golf putting task. *Anxiety, Stress, & Coping, 20*(2), 197-207. doi:10.1080/10615800701288572

Chapman, C., Lane, A. M., Brierley, J. H., & Terry, P. C. (1997). Anxiety, self-confidence and performance in tae kwon-do. *Perceptual and Motor Skills, 85*(3), 1275-1278. doi:10.2466/pms.1997.85.3f.1275

Chatterton, J. R., Vogelsong, K. M., Lu, Y. C., Ellman, A. B., & Hudgens, G. A. (1996). Salivary alpha-amylase as a measure of endogenous adrenergic activity. *Clinical Physiology, 16*(4), 433-448. doi:10.1111/j.1475-097X.1996.tb00731.x

Chiodo, S., Tessitore, A., Cortis, C., Cibelli, G., Lupo, C., Ammendolia, A., . . . Capranica, L. (2011). Stress-related hormonal and psychological changes to official youth taekwondo competitions. *Scandinavian Journal of Medicine & Science in Sports, 21*(1), 111-119. doi:10.1111/j.1600-0838.2009.01046.x

Clarke, P. J. F., MacLeod, C., & Guastella, A. J. (2013). Assessing the role of spatial engagement and disengagement of attention in anxiety-linked attentional bias: A critique of current paradigms and suggestions for future research directions. *Anxiety, Stress & Coping, 26*(1), 1-19. doi:10.1080/10615806.2011.638054

Coelho, R. W., Keller, B., & da Silva, Andressa Melina Becker. (2010). Effect of pre- and postcompetition emotional state on salivary cortisol in top-ranking wrestlers. *Perceptual and Motor Skills, 111*(1), 81-86. doi:10.2466/05.06.25.PMS.111.4.81-86

Cooke, A., Kavussanu, M., McIntyre, D., Boardley, I. D., & Ring, C. (2011). Effects of competitive pressure on expert performance: Underlying psychological, physiological, and kinematic mechanisms. *Psychophysiology, 48*(8), 1146-1156. doi:10.1111/j.1469-8986.2011.01175.x

Cooke, A., Kavussanu, M., McIntyre, D., & Ring, C. (2010). Psychological, muscular and kinematic factors mediate performance under pressure. *Psychophysiology, 47*(6), 1109-1118. doi:10.1111/j.1469-8986.2010.01021.x

Corbetta, M., & Shulman, G. L. (2002). Control of goal-directed and stimulus-driven attention in the brain. *Nature Reviews Neuroscience, 3*(3), 201-215. doi:10.1038/nrn755

Craft, L. L., Magyar, T. M., Becker, B. J., & Feltz, D. L. (2003). The relationship between the competitive state anxiety inventory-2 and sport performance: A meta-analysis. *Journal of Sport and Exercise Psychology, 25*(1), 44-65. doi:10.1123/jsep.25.1.44

Cunniffe, B., Morgan, K. A., Baker, J. S., Cardinale, M., & Davies, B. (2015). Home versus away competition: Effect on psychophysiological variables in elite rugby union. *International Journal of Sports Physiology and Performance, 10*(6), 687-694. doi:10.1123/ijspp.2014-0370

de Wit, M. M., Masters, R. S. W., & van der Kamp, J. (2012). Exploring the thresholds of vision for perception and action. *Motor Control, 16*(1), 120-128. doi:10.1123/mcj.16.1.120

Dedovic, K., Duchesne, A., Andrews, J., Engert, V., & Pruessner, J. C. (2009). The brain and the stress axis: The neural correlates of cortisol regulation in response to stress. *NeuroImage, 47*(3), 864-871. doi:10.1016/j.neuroimage.2009.05.074

Deinzer, R., Kirschbaum, C., Gresele, C., & Hellhammer, D. H. (1997). Adrenocortical responses to repeated parachute jumping and subsequent h-CRH challenge in inexperienced healthy subjects. *Physiology & Behavior, 61*(4), 507-511. doi:10.1016/S0031-9384(96)00465-9

Delay, D., Nougier, V., Orliaguet, J., & Coello, Y. (1997). Movement control in golf putting. *Human Movement Science, 16*(5), 597-619. doi:10.1016/S0167-9457(97)00008-0

Derakshan, N., Ansari, T. L., Hansard, M., Shoker, L., & Eysenck, M. W. (2009). Anxiety, inhibition, efficiency, and effectiveness. an investigation using antisaccade task. *Experimental Psychology, 56*(1), 48-55. doi:10.1027/1618-3169.56.1.48

Derakshan, N., & Eysenck, M. W. (2009). Anxiety, processing efficiency, and cognitive performance: New developments from attentional control theory. *European Psychologist, 14*(2), 168-176. doi:10.1027/1016-9040.14.2.168

Derakshan, N., & Koster, E. H. W. (2010). Processing efficiency in anxiety: Evidence from eye-movements during visual search. *Behaviour Research and Therapy, 48*(12), 1180-1185. doi:10.1016/j.brat.2010.08.009

Díaz, M. M., Bocanegra, O. L., Teixeira, R. R., Tavares, M., Soares, S. S., & Espindola, F. S. (2013). The relationship between the cortisol awakening response, mood states, and performance. *Journal of Strength and Conditioning Research, 27*(5), 1340-1348. doi:10.1519/JSC.0b013e318267a612

Dickerson, S. S., & Kemeny, M. E. (2004). Acute stressors and cortisol responses: A theoretical integration and synthesis of laboratory research. *Psychological Bulletin, 130*(3), 355-391. doi:10.1037/0033-2909.130.3.355

Dickerson, S. S., Mycek, P. J., & Zaldivar, F. (2008). Negative social evaluation, but not mere social presence, elicits cortisol responses to a laboratory stressor task. *Health Psychology, 27*(1), 116-121. doi:10.1037/0278-6133.27.1.116

Dicks, M., Button, C., & Davids, K. (2010). Examination of gaze behaviors under in situ and video simulation task constraints reveals differences in information pickup for perception and action. *Attention, Perception, & Psychophysics, 72*(3), 706-720. doi:10.3758/APP.72.3.706

Dienstbier, R. A. (1989). Arousal and physiological toughness: Implications for mental and physical health. *Psychological Review, 96*(1), 84-100. doi:10.1037/0033-295X.96.1.84

Doan, B. K., Newton, R. U., Kraemer, W. J., Kwon, Y. H., & Scheet, T. P. (2007). Salivary cortisol, testosterone, and T/C ratio responses during a 36-hole golf competition. *International Journal of Sports Medicine, 28*(06), 470-479. doi:10.1055/s-2006-924557

Easterbrook, A. J. (1959). The effect of emotion on cue utilization and the organization of behavior. *Psychological Review, 66*(3), 183-201. doi:10.1037/h0047707

Edwards, D. A., & Kurlander, L. S. (2010). Women's intercollegiate volleyball and tennis: Effects of warm-up, competition, and practice on saliva levels of cortisol and testosterone. *Hormones and Behavior, 58*(4), 606-613. doi:10.1016/j.yhbeh.2010.06.015

Elloumi, M., Ounis, O. B., Tabka, Z., Van Praagh, E., Michaux, O., & Lac, G. (2008). Psychoendocrine and physical performance responses in male tunisian rugby players during an international competitive season. *Aggressive Behavior, 34*(6), 623-632. doi:10.1002/ab.20276

Elzinga, B. M., & Roelofs, K. (2005). Cortisol-induced impairments of working memory require acute sympathetic activation. *Behavioral Neuroscience, 119*(1), 98-103. doi:10.1037/0735-7044.119.1.98

Engert, V., Efanov, S. I., Duchesne, A., Vogel, S., Corbo, V., & Pruessner, J. C. (2013). Differentiating anticipatory from reactive cortisol responses to psychosocial stress. *Psychoneuroendocrinology, 38*(8), 1328-1337. doi:10.1016/j.psyneuen.2012.11.018

Eysenck, M. W., & Calvo, M. G. (1992). Anxiety and performance: The processing efficiency theory. *Cognition & Emotion, 6*(6), 409-434. doi:10.1080/02699939208409696

Eysenck, M. W., & Derakshan, N. (2011). New perspectives in attentional control theory. *Personality and Individual Differences, 50*(7), 955-960. doi:10.1016/j.paid.2010.08.019

Eysenck, M. W., Derakshan, N., Santos, R., & Calvo, M. G. (2007). Anxiety and cognitive performance: Attentional control theory. *Emotion, 7*(2), 336-353. doi:10.1037/1528-3542.7.2.336

Filaire, E., Maso, F., Sagnol, M., Ferrand, C., & Lac, G. (2001). Anxiety, hormonal responses, and coping during a judo competition. *Aggressive Behavior, 27*(1), 55-63. doi:AID-AB5%3E3.0.CO;2-H

Filaire, E., Alix, D., Ferrand, C., & Verger, M. (2009). Psychophysiological stress in tennis players during the first single match of a tournament. *Psychoneuroendocrinology, 34*(1), 150-157. doi:10.1016/j.psyneuen.2008.08.022

Filaire, E., Bonis, J., & Lac, G. (2004). Relationships between physiological and psychological stress and salivary immunoglobulin a among young female gymnasts. *Perceptual and Motor Skills, 99*(2), 605-617. doi:10.2466/pms.99.2.605-617

Fischer, D. G., & Donatelli, M. J. (1987). A measure of stress and arousal: Factor structure of the stress adjective checklist. *Educational and Psychological Measurement, 47*(2), 425-435. doi:10.1177/0013164487472014

Fletcher, D., Hanton, S., & Mellalieu, S. D. (2006). An organizational stress review: Conceptual and theoretical issues in competitive sport. *Literature Reviews in Sport Psychology,* , 321-373.

Friedman, N. P., & Miyake, A. (2004). The relations among inhibition and interference control functions: A latent-variable analysis. *Journal of Experimental Psychology. General, 133*(1), 101-135. doi:10.1037/0096-3445.133.1.101

Gaab, J., Rohleder, N., Nater, U. M., & Ehlert, U. (2005). Psychological determinants of the cortisol stress response: The role of anticipatory cognitive appraisal. *Psychoneuroendocrinology, 30*(6), 599-610. doi:10.1016/j.psyneuen.2005.02.001

Gonzalez-Bono, E., Salvador, A., Serrano, M. A., & Ricarte, J. (1999). Testosterone, cortisol, and mood in a sports team competition. *Hormones and Behavior, 35*(1), 55-62. doi:S0018-506X(98)91496-9

Granger, D. A., Kivlighan, K. T., El-Sheikh, M., Gordis, E. B., & Stroud, L. R. (2007). Salivary α-Amylase in biobehavioral research. *Annals of the New York Academy of Sciences, 1098*(1), 122-144. doi:10.1196/annals.1384.008

Gray, R., & Canal Bruland, R. (2015). Attentional focus, perceived target size and movement kinematics under performance pressure. *Psychonomic Bulletin and Review, 22*(6), 1692-1700. doi:10.3758/s13423-015-0838-z

Gucciardi, D. F., & Dimmock, J. A. (2008). Choking under pressure in sensorimotor skills: Conscious processing or depleted attentional resources? *Psychology of Sport and Exercise, 9*(1), 45-59. doi:10.1016/j.psychsport.2006.10.007

Hancock, G. R., Butler, M. S., & Fischman, M. G. (1995). On the problem of two-dimensional error scores: Measures and analyses of accuracy, bias, and consistency. *Journal of Motor Behavior, 27*(3), 241-250. doi:10.1080/00222895.1995.9941714

Haneishi, K., Fry, A. C., Moore, C. A., Schilling, B. K., Li, Y., & Fry, M. D. (2007). Cortisol and stress responses during a game and practice in female collegiate soccer players. *Journal of Strength and Conditioning Research, 21*(2), 583-588. doi:10.1519/R-20496.1

Hanton, S., Thomas, O., & Maynard, I. (2004). Competitive anxiety responses in the week leading up to competition: The role of intensity, direction and frequency dimensions. *Psychology of Sport and Exercise, 5*(2), 169-181. doi:10.1016/S1469-0292(02)00042-0

Hardy, L. (1997). The coleman roberts griffith address: Three myths about applied consultancy work. *Journal of Applied Sport Psychology, 9*(2), 277-294. doi:10.1080/10413209708406487

Hardy, L., Mullen, R., & Jones, G. (1996). Knowledge and conscious control of motor actions under stress. *British Journal of Psychology, 87*(4), 621-636. doi:10.1111/j.2044-8295.1996.tb02612.x

Hare, O. A., Wetherell, M. A., & Smith, M. A. (2013). State anxiety and cortisol reactivity to skydiving in novice versus experienced skydivers. *Physiology & Behavior, 118*, 40-44. doi:10.1016/j.physbeh.2013.05.011

Harris, B., Cook, N. J., Walker, R. F., Read, G. F., & Riad-Fahmy, D. (1989). Salivary steroids and psychometric parameters in male marathon runners. *British Journal of Sports Medicine, 23*(2), 89-93. doi:10.1136/bjsm.23.2.89

Hase, A., O'Brien, J., Moore, L. J., & Freeman, P. (2018). The relationship between challenge and threat states and performance: A systematic review. *Sport, Exercise, and Performance Psychology,* doi:10.1037/spy0000132

Hasegawa, Y., Koyama, S., & Inomata, K. (2013). Perceived distance during golf putting. *Human Movement Science, 32*(6), 1226-1238. doi:10.1016/j.humov.2013.02.003

Hatfield, B. D., Costanzo, M. E., Goodman, R. N., Lo, L. C., Oh, H., Rietschel, J. C., . . . Haufler, A. (2013). The influence of social evaluation on cerebral cortical activity and motor performance: A study of "real-life" competition. *International Journal of Psychophysiology, 90*(2), 240-249. doi:10.1016/j.ijpsycho.2013.08.002

Hayes, A. F. (2013). *Introduction to mediation, moderation, and conditional process analysis: A regression-based approach*. US: Guilford Publications Inc. M.U.A.

Hayes, L. D., Grace, F. M., Baker, J. S., & Sculthorpe, N. (2015). Exercise-induced responses in salivary testosterone, cortisol, and their ratios in men: A meta-analysis. *Sports Medicine, 45*(5), 713-726. doi:10.1007/s40279-015-0306-y

Hayhoe, M., & Ballard, D. (2005). Eye movements in natural behavior. *Trends in Cognitive Sciences, 9*(4), 188-194. doi:10.1016/j.tics.2005.02.009

Hellhammer, D. H., Wüst, S., & Kudielka, B. M. (2009). Salivary cortisol as a biomarker in stress research. *Psychoneuroendocrinology, 34*(2), 163-171. doi:10.1016/j.psyneuen.2008.10.026

Henry, J. P. (1992). Biological basis of the stress response. *Integrative Physiological and Behavioral Science, 27*(1), 66-83. doi:10.1007/BF02691093

Hoogendam, J., Lijn, F., Vernooij, M., Hofman, A., Niessen, W., Lugt, A., . . . Geest, J. (2014). Older age relates to worsening of fine motor skills: A population based study of middle-aged and elderly persons. *Frontiers in Aging Neuroscience, 6*(SEP), 259. doi:10.3389/fnagi.2014.00259

Hoshiyama, M., Kakigi, R., Watanabe, S., Miki, K., & Takeshima, Y. (2003). Brain responses for the subconscious recognition of faces. *Neuroscience Research, 46*(4), 435-442. doi:10.1016/S0168-0102(03)00121-4

Houtman, I. L., & Bakker, F. C. (1989). The anxiety thermometer: A validation study. *Journal of Personality Assessment, 53*(3), 575-582. doi:10.1207/s15327752jpa5303_14

Hucklebridge, F., Clow, A., & Evans, P. (1998). The relationship between salivary secretory immunoglobulin A and cortisol: Neuroendocrine response to awakening and the diurnal cycle. *International Journal of Psychophysiology, 31*(1), 69-76. doi:10.1016/S0167-8760(98)00042-7

Hüttermann, S., & Memmert, D. (2014). Does the inverted-U function disappear in expert athletes? an analysis of the attentional behavior under physical exercise of athletes and non-athletes. *Physiology & Behavior, 131*, 87-92. doi:10.1016/j.physbeh.2014.04.020

Iellamo, F., Pigozzi, F., Parisi, A., Salvo, V. D., & al, e. (2003). The stress of competition dissociates neural and cortisol homeostasis in elite athletes. *Journal of Sports Medicine and Physical Fitness, 43*(4), 539-45.

Ioannou, C. I., Furuya, S., & Altenmüller, E. (2016). The impact of stress on motor performance in skilled musicians suffering from focal dystonia: Physiological and psychological characteristics. *Neuropsychologia, 85*, 226-236. doi:10.1016/j.neuropsychologia.2016.03.029

Jacks, D. E., Sowash, J., Anning, J., McGloughlin, T., & Andres, F. (2002). Effect of exercise at three exercise intensities on salivary cortisol. *Journal of Strength and Conditioning Research, 16*(2), 286-289.

Janelle, C. M. (2002). Anxiety, arousal and visual attention: A mechanistic account of performance variability. *Journal of Sports Sciences, 20*(3), 237-251. doi:10.1080/026404102317284790

Janelle, C. M., Singer, R. N., & Williams, A. M. (1999). External distraction and attentional narrowing: Visual search evidence. *Journal of Sport and Exercise Psychology, 21*(1), 70-91. doi:10.1123/jsep.21.1.70

Jones, G. (1995). More than just a game: Research developments and issues in competitive anxiety in sport. *British Journal of Psychology, 86*(4), 449-478. doi:10.1111/j.2044-8295.1995.tb02565.x

Jones, G., & Swain, A. (1992). Intensity and direction as dimensions of competitive state anxiety and relationships with competitiveness. *Perceptual and Motor Skills, 74*(2), 467-472. doi:10.2466/pms.1992.74.2.467

Jones, M. V., & Uphill, M. (2004). Responses to the competitive state anxiety inventory-2(d) by athletes in anxious and excited scenarios. *Psychology of Sport and Exercise, 5*(2), 2001-2012. doi:10.1016/S1469-0292(02)00054-7

Jones, M., Meijen, C., McCarthy, P. J., & Sheffield, D. (2009). A theory of challenge and threat states in athletes. *International Review of Sport and Exercise Psychology, 2*(2), 161-180. doi:10.1080/17509840902829331

Karlsen, J., Smith, G., & Nilsson, J. (2008). The stroke has only a minor influence on direction consistency in golf putting among elite players. *Journal of Sports Sciences, 26*(3), 243-250. doi:10.1080/02640410701530902

Kirschbaum, C., Klauer, T., Filipp, S. H., & Hellhammer, D. H. (1995). Sex-specific effects of social support on cortisol and subjective responses to acute psychological stress. *Psychosomatic Medicine, 57*(1), 23-31. doi:10.1097/00006842-199501000-00004

Kirschbaum, C., Wüst, S., & Hellhammer, D. (1992). Consistent sex differences in cortisol responses to psychological stress. *Psychosomatic Medicine, 54*(6), 648-657. doi:10.1097/00006842-199211000-00004

Kirschbaum, C., & Hellhammer, D. H. (1994). Salivary cortisol in psychoneuroendocrine research: Recent developments and applications. *Psychoneuroendocrinology, 19*(4), 313-333. doi:10.1016/0306-4530(94)90013-2

Kirschbaum, C., & Hellhammer, D. H. (1999). Noise and stress - salivary cortisol as a non-invasive measure of allostatic load. *Noise & Health, 1*(4), 57-66.

Kivlighan, K. T., & Granger, D. A. (2006). Salivary a-amylase response to competition: Relation to gender, previous experience, and attitudes. *Psychoneuroendocrinology, 31*(6), 703-714. doi:10.1016/j.psyneuen.2006.01.007

Kivlighan, K. T., Granger, D. A., & Booth, A. (2005). Gender differences in testosterone and cortisol response to competition. *Psychoneuroendocrinology, 30*(1), 58-71. doi:10.1016/j.psyneuen.2004.05.009

Koo, T. K., & Li, M. Y. (2016). A guideline of selecting and reporting intraclass correlation coefficients for reliability research. *Journal of Chiropractic Medicine, 15*(2), 155-163. doi:10.1016/j.jcm.2016.02.012

Krane, V. (1994). The mental readiness form as a measure of competitive state anxiety. *The Sport Psychologist, 8*(2), 189-202. doi:10.1123/tsp.8.2.189

Krane, V., Williams, J., & Feltz, D. (1992). Path analysis examining relationships among cognitive anxiety, somatic anxiety, state confidence, performance expectations, and golf performance. *Journal of Sport Behavior, 15*(4), 279–295.

Kudielka, B. M., Buske-Kirschbaum, A., Hellhammer, D. H., & Kirschbaum, C. (2004). HPA axis responses to laboratory psychosocial stress in healthy elderly adults, younger adults, and children: Impact of age and gender. *Psychoneuroendocrinology, 29*(1), 83-98. doi:10.1016/S0306-4530(02)00146-4

Kudielka, B. M., & Kirschbaum, C. (2005). Sex differences in HPA axis responses to stress: A review. *Biological Psychology, 69*(1), 113-132. doi:10.1016/j.biopsycho.2004.11.009

Kudielka, B. M., Hellhammer, D. H., & Wüst, S. (2009). Why do we respond so differently? reviewing determinants of human salivary cortisol responses to challenge. *Psychoneuroendocrinology, 34*(1), 2-18. doi:10.1016/j.psyneuen.2008.10.004

Land, M. F. (2009). Vision, eye movements, and natural behavior. *Visual Neuroscience, 26*(1), 51-62. doi:10.1017/S0952523808080899

Land, W., & Tenenbaum, G. (2012). An outcome- and process-oriented examination of a golf-specific secondary task strategy to prevent choking under pressure. *Journal of Applied Sport Psychology, 24*(3), 303-322. doi:10.1080/10413200.2011.642458

Lane, A. M., Sewell, D. F., Terry, P. C., Bartram, D., & Nesti, M. S. (1999). Confirmatory factor analysis of the competitive state anxiety inventory-2. *Journal of Sports Sciences, 17*(6), 505-512. doi:10.1080/026404199365812

Lautenbach, F., Laborde, S., Achtzehn, S., & Raab, M. (2014). Preliminary evidence of salivary cortisol predicting performance in a controlled setting. *Psychoneuroendocrinology, 42*, 218-224. doi:10.1016/j.psyneuen.2014.01.011

Lautenbach, F. (2017). A laboratory study on attentional bias as an underlying mechanism affecting the link between cortisol and performance, leading to a discussion on the nature of the stressor (artificial vs. psychosocial). *Physiology & Behavior, 175*(Supplement C), 9-15. doi:10.1016/j.physbeh.2017.03.022

Lautenbach, F., & Laborde, S. (2016). The influence of hormonal stress on performance. In M. Raab, B. Lobinger, S. Hoffman, A. Pizzera & S. Laborde (Eds.), *Performance psychology. perception, action, cognition, and emotion* (pp. 315-328). San Diego: Academic Press.

Law, J., Masters, R., Bray, S. R., Eves, F., & Bardswell, I. (2003). Motor performance as a function of audience affability and metaknowledge. *Journal of Sport and Exercise Psychology, 25*(4), 484-500. doi:10.1123/jsep.25.4.484

Lazarus, R. S. (2000). How emotions influence performance in competitive sports. *The Sport Psychologist, 14*(3), 229-252. doi:10.1123/tsp.14.3.229

Lazarus, R. S., Deese, J., & Osler, S. F. (1952). The effects of psychological stress upon performance. *Psychological Bulletin, 49*(4), 293-317.

Levy, B. J., & Wagner, A. D. (2011). Cognitive control and right ventrolateral prefrontal cortex: Reflexive reorienting, motor inhibition, and action updating. *Annals of the New York Academy of Sciences, 1224*(1), 40-62. doi:10.1111/j.1749-6632.2011.05958.x

Lovallo, W. R., & Thomas, T. L. (2000). Stress hormones in psychophysiological research: Emotional, behavioral, and cognitive implications. In J. T. Cacioppo, L. G. Tassinary & G. G. Berntson (Eds.), *Handbook of psychophysiology, 2nd ed* (pp. 342-367). New York, NY, US: Cambridge University Press.

Mackay, C., Cox, T., Burrows, G., & Lazzerini, T. (1978). An inventory for the measurement of self-reported stress and arousal. *British Journal of Social and Clinical Psychology, 17*(3), 283-284. doi:10.1111/j.2044-8260.1978.tb00280.x

Mann, D. T. Y., Williams, A. M., Ward, P., & Janelle, C. M. (2007). Perceptual-cognitive expertise in sport: A meta-analysis. *Journal of Sport and Exercise Psychology, 29*(4), 457-478. doi:10.1123/jsep.29.4.457

Martens, R., Vealey, R. S., & Burton, D. (1990). *Competitive anxiety in sport*. Champaign, Illinois: Human kinetics.

Mascret, N., Ibáñez-Gijón, J., Bréjard, V., Buekers, M., Casanova, R., Marqueste, T., . . . Cury, F. (2016). The influence of the 'Trier social stress test' on free throw performance in basketball: An interdisciplinary study. *Plos One, 11*(6), e0157215. doi:10.1371/journal.pone.0157215

Masters, R. S. W. (1992). Knowledge, knerves and know-how: The role of explicit versus implicit knowledge in the breakdown of a complex motor skill under pressure. *British Journal of Psychology, 83*(3), 343–358. doi:10.1111/j.2044-8295.1992.tb02446.x

McKay, J. M., Selig, S. E., Carlson, J. S., & Morris, T. (1997). Psychophysiological stress in elite golfers during practice and competition. *Australian Journal of Science and Medicine in Sport, 29*(2), 55-61.

McLellan, C. P., Lovell, D. I., & Gass, G. C. (2011). Biochemical and endocrine responses to impact and collision during elite rugby league match play. *Journal of Strength and Conditioning Research, 25*(6), 1553-1562. doi:10.1519/JSC.0b013e3181db9bdd

Mellalieu, S. D., Hanton, S., & O'Brien, M. (2004). Intensity and direction of competitive anxiety as a function of sport type and experience. *Scandinavian Journal of Medicine & Science in Sports, 14*(5), 326-334. doi:10.1111/j.1600-0838.2004.00389.x

Mellalieu, S. D., Neil, R., Hanton, S., & Fletcher, D. (2009). Competition stress in sport performers: Stressors experienced in the competition environment. *Journal of Sports Sciences, 27*(7), 729-744. doi:10.1080/02640410902889834

Mesagno, C., Harvey, J. T., & Janelle, C. M. (2011). Self-presentation origins of choking: Evidence from separate pressure manipulations. *Journal of Sport and Exercise Psychology, 33*(3), 441-459. doi:10.1123/jsep.33.3.441

Metz, G. A., Jadavji, N. M., & Smith, L. K. (2005). Modulation of motor function by stress: A novel concept of the effects of stress and corticosterone on behavior. *The European Journal of Neuroscience, 22*(5), 1190-1200. doi:10.1111/j.1460-9568.2005.04285.x

Meyer, V. J., Lee, Y., Böttger, C., Leonbacher, U., Allison, A. L., & Shirtcliff, E. A. (2015). Experience, cortisol reactivity, and the coordination of emotional responses to skydiving. *Frontiers in Human Neuroscience, 9*, 138. doi:10.3389/fnhum.2015.00138

Miller, R., Plessow, F., Kirschbaum, C., & Stalder, T. (2013). Classification criteria for distinguishing cortisol responders from nonresponders to psychosocial stress: Evaluation of salivary cortisol pulse detection in panel designs. *Psychosomatic Medicine, 75*(9), 832-840. doi:10.1097/PSY.0000000000000002

Moher, D., Liberati, A., Tetzlaff, J., Altman, D. G., & Group, T. P. (2009). Preferred reporting items for systematic reviews and meta-analyses: The PRISMA statement. *PLOS Medicine, 6*(7), e1000097. doi:10.1371/journal.pmed.1000097

Moore, L. J., Vine, S. J., Cooke, A., Ring, C., & Wilson, M. R. (2012). Quiet eye training expedites motor learning and aids performance under heightened anxiety: The roles of response programming and external attention. *Psychophysiology, 49*(7), 1005-1015. doi:10.1111/j.1469-8986.2012.01379.x

Moore, L. J., Vine, S. J., Wilson, M. R., & Freeman, P. (2012). The effect of challenge and threat states on performance: An examination of potential mechanisms. *Psychophysiology, 49*(10), 1417-1425. doi:10.1111/j.1469-8986.2012.01449.x

Moore, L. J., Wilson, M. R., Vine, S. J., Coussens, A. H., & Freeman, P. (2013). Champ or chump?: Challenge and threat states during pressurized competition. *Journal of Sport and Exercise Psychology, 35*(6), 551-562. doi:10.1123/jsep.35.6.551

Moran, T. P., & Moser, J. S. (2015). The color of anxiety: Neurobehavioral evidence for distraction by perceptually salient stimuli in anxiety. *Cognitive, Affective & Behavioral Neuroscience, 15*(1), 169-179. doi:10.3758/s13415-014-0314-7

Moreira, A., Bacurau, R. F. P., Napimoga, M. H., Arruda, A. F. S., Freitas, C. G., Drago, G., & Aoki, M. S. (2014). Salivary IL-21 and IgA responses to a competitive match in elite basketball players. *Biology of Sport, 30*(4), 243-247. doi:10.5604/20831862.1077548

Morris, L. W., Davis, M. A., & Hutchings, C. H. (1981). Cognitive and emotional components of anxiety: Literature review and a revised worry-emotionality scale. *Journal of Educational Psychology, 73*(4), 541-555.

Mullen, R., & Hardy, L. (2000). State anxiety and motor performance: Testing the conscious processing hypothesis. *Journal of Sports Sciences, 18*(10), 785-799. doi:10.1080/026404100419847

Mullen, R., Hardy, L., & Tattersall, A. (2005). The effects of anxiety on motor performance: A test of the conscious processing hypothesis. *Journal of Sport and Exercise Psychology, 27*(2), 212-225. doi:10.1123/jsep.27.2.212

Mullen, R., Jones, E. S., Oliver, S., & Hardy, L. (2016). Anxiety and motor performance: More evidence for the effectiveness of holistic process goals as a solution to the process goal paradox. *Psychology of Sport and Exercise, 27*, 142-149. doi:10.1016/j.psychsport.2016.08.009

Murphy, L., Denis, R., Ward, C. P., & Tartar, J. L. (2010). Academic stress differentially influences perceived stress, salivary cortisol, and immunoglobulin-A in undergraduate students. *Stress, 13*(4), 366-371. doi:10.3109/10253891003615473

Murray, E. (2016, Apr 11,). Masters 2016: Danny willett wins after jordan spieth's disaster at the 12th. *The Guardian* Retrieved from https://tinyurl.com/ya4smy9t

Murray, N. P., & Janelle, C. M. (2003). Anxiety and performance: A visual search examination of the processing efficiency theory. *Journal of Sport and Exercise Psychology, 25*(2), 171-187. doi:10.1123/jsep.25.2.171

Nater, U. M., Moor, C., Okere, U., Stallkamp, R., Martin, M., Ehlert, U., & Kliegel, M. (2007). Performance on a declarative memory task is better in high than low cortisol responders to psychosocial stress. *Psychoneuroendocrinology, 32*(6), 758-763. doi:10.1016/j.psyneuen.2007.05.006

Nater, U. M., & Rohleder, N. (2009). Salivary alpha-amylase as a non-invasive biomarker for the sympathetic nervous system: Current state of research. *Psychoneuroendocrinology, 34*(4), 486-496. doi:10.1016/j.psyneuen.2009.01.014

Nater, U. M., Rohleder, N., Gaab, J., Berger, S., Jud, A., Kirschbaum, C., & Ehlert, U. (2005). Human salivary alpha-amylase reactivity in a psychosocial stress paradigm. *International Journal of Psychophysiology, 55*(3), 333-342. doi:10.1016/j.ijpsycho.2004.09.009

Neukirchen, M., & Kienbaum, P. (2008). Sympathetic nervous system: Evaluation and importance for clinical general anesthesia. *Anesthesiology, 109*(6), 1113-1131. doi:10.1097/ALN.0b013e31818e435c

Nibbeling, N., Oudejans, R. R. D., & Daanen, H. A. M. (2012). Effects of anxiety, a cognitive secondary task, and expertise on gaze behavior and performance in a far aiming task. *Psychology of Sport and Exercise, 13*(4), 427-435. doi:10.1016/j.psychsport.2012.02.002

Nieuwenhuys, A., & Oudejans, R. R. D. (2012). Anxiety and perceptual-motor performance: Toward an integrated model of concepts, mechanisms, and processes. *Psychological Research, 76*(6), 747-759. doi:10.1007/s00426-011-0384-x

Nieuwenhuys, A., Pijpers, J. R., Oudejans, R. R. D., & Bakker, F. C. (2008). The influence of anxiety on visual attention in climbing. *Journal of Sport and Exercise Psychology, 30*(2), 171-185. doi:10.1123/jsep.30.2.171

Nieuwenhuys, A., Savelsbergh, G. J. P., & Oudejans, R. R. D. (2012). Shoot or don't shoot? why police officers are more inclined to shoot when they are anxious. *Emotion, 12*(4), 827-833. doi:10.1037/a0025699

O'Donnell, K., Kammerer, M., O'Reilly, R., Taylor, A., & Glover, V. (2009). Salivary alpha-amylase stability, diurnal profile and lack of response to the cold hand test in young women. *Stress, 12*(6), 549-554. doi:10.3109/10253890902822664

Oei, N. Y. L., Everaerd, W. T., Elzinga, B. M., Well, S. v., & Bermond, B. (2006). Psychosocial stress impairs working memory at high loads: An association with cortisol levels and memory retrieval. *Stress, 9*(3), 133-141. doi:10.1080/10253890600965773

Oliveira, T., Gouveia, M. J., & Oliveira, R. F. (2009). Testosterone responsiveness to winning and losing experiences in female soccer players. *Psychoneuroendocrinology, 34*(7), 1056-1064. doi:10.1016/j.psyneuen.2009.02.006

Otten, M. (2009). Choking vs. clutch performance: A study of sport performance under pressure. *Journal of Sport & Exercise Psychology, 31*(5), 583-601. doi:10.1123/jsep.31.5.583

Pham, Q. C., & Hicheur, H. (2009). On the open-loop and feedback processes that underlie the formation of trajectories during visual and nonvisual locomotion in humans. *Journal of Neurophysiology, 102*(5), 2800-2815. doi:10.1152/jn.00284.2009

Piacentini, M. F., Minganti, C., Ferragina, A., Ammendolia, A., Capranica, L., & Cibelli, G. (2015). Stress related changes during a half marathon in master endurance athletes. *The Journal of Sports Medicine and Physical Fitness, 55*(4), 329-336.

Pijpers, J. R., Oudejans, R. R. D., Bakker, F. C., & Beek, P. J. (2006). The role of anxiety in perceiving and realizing affordances. *Ecological Psychology, 18*(3), 131-161. doi:10.1207/s15326969eco1803_1

Pijpers, J. R., Oudejans, R. R. D., Holsheimer, F., & Bakker, F. C. (2003). Anxiety–performance relationships in climbing: A process-oriented approach. *Psychology of Sport and Exercise, 4*(3), 283-304. doi:10.1016/S1469-0292(02)00010-9

Posner, M. I. (1980). Orienting of attention. *The Quarterly Journal of Experimental Psychology, 32*(1), 3-25. doi:10.1080/00335558008248231

Putman, P., & Berling, S. (2011). Cortisol acutely reduces selective attention for erotic words in healthy young men. *Psychoneuroendocrinology, 36*(9), 1407-1417. doi:10.1016/j.psyneuen.2011.03.015

Qin, S., Hermans, E. J., van-Marle, H. J. F., Luo, J., & Fernández, G. (2009). Acute psychological stress reduces working memory-related activity in the dorsolateral prefrontal cortex. *Biological Psychiatry, 66*(1), 25-32. doi:10.1016/j.biopsych.2009.03.006

Quaedflieg, C. W., Van, V. d. V., Meyer, T., Siep, N., Merckelbach, H., & Smeets, T. (2015). Temporal dynamics of stress-induced alternations of intrinsic amygdala connectivity and neuroendocrine levels., temporal dynamics of stress-induced alternations of intrinsic amygdala connectivity and neuroendocrine levels. *PloS One, 10*(5), e0124141. doi:10.1371/journal.pone.0124141

Rimmele, U., Zellweger, B. C., Marti, B., Seiler, R., Mohiyeddini, C., Ehlert, U., & Heinrichs, M. (2007). Trained men show lower cortisol, heart rate and psychological responses to psychosocial stress compared with untrained men. *Psychoneuroendocrinology, 32*(6), 627-635. doi:10.1016/j.psyneuen.2007.04.005

Robazza, C., Gallina, S., D'Amico, M. A., Izzicupo, P., Bascelli, A., Di Fonso, A., . . . Di Baldassarre, A. (2012). Relationship between biological markers and psychological states in elite basketball players across a competitive season. *Psychology of Sport and Exercise, 13*(4), 509-517. doi:10.1016/j.psychsport.2012.02.011

Rohleder, N., Nater, U. M., Wolf, J. M., Ehlert, U., & Kirschbaum, C. (2004). Psychosocial stress-induced activation of salivary alpha-amylase: An indicator of sympathetic activity? *Annals of the New York Academy of Sciences, 1032*(1), 258-263. doi:10.1196/annals.1314.033

Rohleder, N., Wolf, J. M., Maldonado, E. F., & Kirschbaum, C. (2006). The psychosocial stress-induced increase in salivary alpha-amylase is independent of saliva flow rate. *Psychophysiology, 43*(6), 645-652. doi:10.1111/j.1469-8986.2006.00457.x

Rossato, C. J. L., Uphill, M. A., Swain, J., & Coleman, D. A. (2016). The development and preliminary validation of the challenge and threat in sport (CAT-sport) scale. *International Journal of Sport and Exercise Psychology,* , 1-14. doi:10.1080/1612197X.2016.1182571

Salthouse, T. A., Ellis, C. L., Diener, D. C., & Somberg, B. L. (1981). Stimulus processing during eye fixations. *Journal of Experimental Psychology: Human Perception and Performance, 7*(3), 611-623. doi:10.1037/0096-1523.7.3.611

Salvador, A., Suay, F., González-Bono, E., & Serrano, M. A. (2003). Anticipatory cortisol, testosterone and psychological responses to judo competition in young men. *Psychoneuroendocrinology, 28*(3), 364-375. doi:10.1016/S0306-4530(02)00028-8

Salvador, A. (2005). Coping with competitive situations in humans. *Neuroscience & Biobehavioral Reviews, 29*(1), 195-205. doi:10.1016/j.neubiorev.2004.07.004

Salvucci, D. D., & Goldberg, J. H.Identifying fixations and saccades in eye-tracking protocols. 71–78. doi:10.1145/355017.355028

Sarason, I. G. (1988). Anxiety, self-preoccupation and attention. *Anxiety Research, 1*(1), 3-7. doi:10.1080/10615808808248215

Schwabe, L., Haddad, L., & Schachinger, H. (2008). HPA axis activation by a socially evaluated cold-pressor test. *Psychoneuroendocrinology, 33*(6), 890-895. doi:10.1016/j.psyneuen.2008.03.001

Schwabe, L., Höffken, O., Tegenthoff, M., & Wolf, O. T. (2013). Stress-induced enhancement of response inhibition depends on mineralocorticoid receptor activation. *Psychoneuroendocrinology, 38*(10), 2319-2326. doi:10.1016/j.psyneuen.2013.05.001

Schwabe, L., Oitzl, M. S., Richter, S., & Schächinger, H. (2009). Modulation of spatial and stimulus–response learning strategies by exogenous cortisol in healthy young women. *Psychoneuroendocrinology, 34*(3), 358-366. doi:10.1016/j.psyneuen.2008.09.018

Seery, M. D. (2013). The biopsychosocial model of challenge and threat: Using the heart to measure the mind. *Social and Personality Psychology Compass, 7*(9), 637-653. doi:10.1111/spc3.12052

Seifert, L., Button, C., & Davids, K. (2013). Key properties of expert movement systems in sport : An ecological dynamics perspective. *Sports Medicine, 43*(3), 167-178. doi:10.1007/s40279-012-0011-z

Shields, G. S., Bonner, J. C., & Moons, W. G. (2015). Does cortisol influence core executive functions? A meta-analysis of acute cortisol administration effects on working memory, inhibition, and set-shifting. *Psychoneuroendocrinology, 58*, 91-103. doi:10.1016/j.psyneuen.2015.04.017

Shields, G. S., Sazma, M. A., & Yonelinas, A. P. (2016). The effects of acute stress on core executive functions: A meta-analysis and comparison with cortisol. *Neuroscience & Biobehavioral Reviews, 68*(Supplement C), 651-668. doi:10.1016/j.neubiorev.2016.06.038

Silva, V., Carvalho, A., Grande, A. J., Martimbianco, A., Riera, R., & Atallah, A. N. (2012). Can data extraction from figures perform a meta-analysis. *Cochrane Database Syst Rev,* doi:10.1002/14651858.CD201200

Skosnik, P. D., Chatterton, R. T., Swisher, T., & Park, S. (2000). Modulation of attentional inhibition by norepinephrine and cortisol after psychological stress. *International Journal of Psychophysiology, 36*(1), 59-68. doi:10.1016/S0167-8760(99)00100-2

Sørensen, T. A., & Barratt, D. (2014). Is threat the only modulator of attentional selectivity? redefining the easterbrook hypothesis. *Frontiers in Psychology, 5* doi:10.3389/fpsyg.2014.01020

Sperlich, B., Achtzehn, S., Buhr, M., Zinner, C., Zelle, S., & Holmberg, H. (2012). Salivary cortisol, heart rate, and blood lactate responses during elite downhill mountain bike racing. *International Journal of Sports Physiology and Performance, 7*(1), 47-52. doi:10.1123/ijspp.7.1.47

Spielberger, C. D. (1966). Theory and research on anxiety. *Anxiety and Behavior, 1*, 3-20.

Spielberger, C. D., Gorsuch, R. L., & Lushene, R. E. (1970). *STAI manual*. Palo Alto, Calif: Consulting Psychologists Pr.

Stauble, M. R., Thompson, L. A., & Morgan, G. (2013). Increases in cortisol are positively associated with gains in encoding and maintenance working memory performance in young men. *Stress, 16*(4), 402-410. doi:10.3109/10253890.2013.780236

Steinbeis, N., Engert, V., Linz, R., & Singer, T. (2015). The effects of stress and affiliation on social decision-making: Investigating the tend-and-befriend pattern. *Psychoneuroendocrinology, 62*(Supplement C), 138-148. doi:10.1016/j.psyneuen.2015.08.003

Steptoe, A., & Ussher, M. (2006). Smoking, cortisol and nicotine. *International Journal of Psychophysiology, 59*(3), 228-235. doi:10.1016/j.ijpsycho.2005.10.011

Strazdins, L., Meyerkort, S., Brent, V., D'Souza, R. M., Broom, D. H., & Kyd, J. M. (2005). Impact of saliva collection methods on sIgA and cortisol assays and acceptability to participants. *Journal of Immunological Methods, 307*(1), 167-171. doi:10.1016/j.jim.2005.09.010

Stroud, L. R., Salovey, P., & Epel, E. S. (2002). Sex differences in stress responses: Social rejection versus achievement stress. *Biological Psychiatry, 52*(4), 318-327. doi:10.1016/S0006-3223(02)01333-1

Tanaka, Y., & Sekiya, H. (2010). The influence of audience and monetary reward on the putting kinematics of expert and novice golfers. *Research Quarterly for Exercise and Sport, 81*(4), 416-424. doi:10.1080/02701367.2010.10599702

Tatler, B. W., Hayhoe, M. M., Land, M. F., & Ballard, D. H. (2011). Eye guidance in natural vision: Reinterpreting salience. *Journal of Vision, 11*(5), 5. doi:10.1167/11.5.5

Taylor, S. E., Seeman, T. E., Eisenberger, N. I., Kozanian, T. A., Moore, A. N., & Moons, W. G. (2010). Effects of a supportive or an unsupportive audience on biological and psychological responses to stress. *Journal of Personality and Social Psychology, 98*(1), 47-56. doi:10.1037/a0016563

Taylor, V. A., Ellenbogen, M. A., Washburn, D., & Joober, R. (2011). The effects of glucocorticoids on the inhibition of emotional information: A dose–response study. *Biological Psychology, 86*(1), 17-25. doi:10.1016/j.biopsycho.2010.10.001

Terry, P. C., Cox, J. A., Lane, A. M., & Karageorghis, C. I. (1996). Measures of anxiety among tennis players in singles and doubles matches. *Perceptual and Motor Skills, 83*(2), 595-603. doi:10.2466/pms.1996.83.2.595

Thatcher, J., Thatcher, R., & Dorling, D. (2004). Gender differences in the pre-competition temporal patterning of anxiety and hormonal responses. *Journal of Sports Medicine and Physical Fitness, 44*(3), 300-308.

Thoma, M. V., Kirschbaum, C., Wolf, J. M., & Rohleder, N. (2012). Acute stress responses in salivary alpha-amylase predict increases of plasma norepinephrine. *Biological Psychology, 91*(3), 342-348. doi:10.1016/j.biopsycho.2012.07.008

Thorn, L., Hucklebridge, F., Evans, P., & Clow, A. (2009). The cortisol awakening response, seasonality, stress and arousal: A study of trait and state influences. *Psychoneuroendocrinology, 34*(3), 299-306. doi:10.1016/j.psyneuen.2008.11.005

Timmis, M. A., Allsop, J., Baranian, M., Baker, J., Basevitch, I., Latham, K., . . . van Paridon, K. N. (2017). Visual search behavior in individuals with retinitis pigmentosa during level walking and obstacle crossing. *Investigative Ophthalmology & Visual Science, 58*(11), 4737-4746. doi:10.1167/iovs.17-21573

Tsafnat, G., Glasziou, P., Choong, M. K., Dunn, A., Galgani, F., & Coiera, E. (2014). Systematic review automation technologies. *Systematic Reviews, 3*, 74-74. doi:10.1186/2046-4053-3-74

Turner, M. J., Jones, M. V., Sheffield, D., & Cross, S. L. (2012). Cardiovascular indices of challenge and threat states predict competitive performance. *International Journal of Psychophysiology, 86*(1), 48-57. doi:10.1016/j.ijpsycho.2012.08.004

Turner, M. J., Jones, M. V., Sheffield, D., Slater, M. J., Barker, J. B., & Bell, J. J. (2013). Who thrives under pressure? predicting the performance of elite academy cricketers using the cardiovascular indicators of challenge and threat states. *Journal of Sport and Exercise Psychology, 35*(4), 387-397. doi:10.1123/jsep.35.4.387

Uhart, M., Chong, R. Y., Oswald, L., Lin, P., & Wand, G. S. (2006). Gender differences in hypothalamic–pituitary–adrenal (HPA) axis reactivity. *Psychoneuroendocrinology, 31*(5), 642-652. doi:10.1016/j.psyneuen.2006.02.003

van den Bosch, J A, de Geus, E J C, Carroll, D., Goedhart, A. D., Anane, L. A., van Zanten, J. J., . . . Edwards, K. M. (2009). A general enhancement of autonomic and cortisol responses during social evaluative threat. *Psychosomatic Medicine, 71*(8), 877-885. doi:10.1097/PSY.0b013e3181baef05

van Paridon, K. N., Timmis, M. A., Nevison, C. M., & Bristow, M. (2017). The anticipatory stress response to sport competition; a systematic review with meta-analysis of cortisol reactivity. *BMJ Open Sport & Exercise Medicine, 3*, e000261. doi:10.1136/bmjsem-2017-000261

van Rullen, R., & Thorpe, S. J. (2001). The time course of visual processing: From early perception to decision-making. *Journal of Cognitive Neuroscience, 13*(4), 454-461. doi:10.1162/08989290152001880

van Stegeren, A. H., Rohleder, N., Everaerd, W., & Wolf, O. T. (2006). Salivary alpha amylase as marker for adrenergic activity during stress: Effect of betablockade. *Psychoneuroendocrinology, 31*(1), 137-141. doi:10.1016/j.psyneuen.2005.05.012

van Stegeren, A. H., Wolf, O. T., & Kindt, M. (2008). Salivary alpha amylase and cortisol responses to different stress tasks: Impact of sex. *International Journal of Psychophysiology, 69*(1), 33-40. doi:10.1016/j.ijpsycho.2008.02.008

Vickers, J. N. (2007). *Perception, cognition, and decision training; the quiet eye in action*. Champaign, Illinois: Human Kinetics, Inc.

Vickers, J. N., & Williams, A. M. (2007). Performing under pressure: The effects of physiological arousal, cognitive anxiety, and gaze control in biathlon. *Journal of Motor Behavior, 39*(5), 381-394. doi:10.3200/JMBR.39.5.381-394

Vickers, J. N. (1992). Gaze control in putting. *Perception, 21*(1), 117-132. doi:10.1068/p210117

Vine, S. J., Lee, D., Moore, L. J., & Wilson, M. R. (2013). Quiet eye and choking: Online control breaks down at the point of performance failure. *Medicine and Science in Sports and Exercise, 45*(10), 1988-1994. doi:10.1249/MSS.0b013e31829406c7

Vine, S. J., Moore, L. J., & Wilson, M. R. (2016). An integrative framework of stress, attention, and visuomotor performance. *Frontiers in Psychology, 7* doi:10.3389/fpsyg.2016.01671

Vlaskamp, B. N. S., Over, E. A. B., & Hooge, I. T. C. (2005). Saccadic search performance: The effect of element spacing. *Experimental Brain Research, 167*(2), 246-259. doi:10.1007/s00221-005-0032-z

Weckesser, L. J., Alexander, N. C., Kirschbaum, C., Mennigen, E., & Miller, R. (2016). Hydrocortisone counteracts adverse stress effects on dual-task performance by improving visual sensory processes. *Journal of Cognitive Neuroscience, 28*(11), 1-20. doi:10.1162/jocn_a_01006

Whitney, D., & Levi, D. M. (2011). Visual crowding: A fundamental limit on conscious perception and object recognition. *Trends in Cognitive Sciences, 15*(4), 160-168. doi:10.1016/j.tics.2011.02.005

Wiemers, U. S., Schoofs, D., & Wolf, O. T. (2013). A friendly version of the trier social stress test does not activate the HPA axis in healthy men and women. *Stress, 16*(2), 254-260. doi:10.3109/10253890.2012.714427

Williams, A. M., Davids, K., Burwitz, L., & Williams, J. G. (1994). Visual search strategies in experienced and inexperienced soccer players. *Research Quarterly for Exercise and Sport, 65*(2), 127-135. doi:10.1080/02701367.1994.10607607

Williams, A. M., Davids, K., & Williams, J. G. (1999). *Visual perception and action in sport* Routledge Ltd. doi:10.4324/9780203979952

Williams, A. M., & Elliott, D. (1999). Anxiety, expertise, and visual search strategy in karate. *Journal of Sport and Exercise Psychology, 21*(4), 362-375. doi:10.1123/jsep.21.4.362

Williams, A. M., Vickers, J., & Rodrigues, S. (2001). The effects of anxiety on visual search, movement kinematics, and performance in table tennis: A test of eysenck and calvo's processing efficiency theory. *Journal of Sport and Exercise Psychology, 23*(4), 438-455. doi:10.1123/jsep.23.4.438

Wilson, M. R., Smith, N. C., & Holmes, P. S. (2007). The role of effort in influencing the effect of anxiety on performance: Testing the conflicting predictions of processing efficiency theory and the conscious processing hypothesis. *British Journal of Psychology, 98*(3), 411-428. doi:10.1348/000712606X133047

Wilson, M. R. (2008). From processing efficiency to attentional control: A mechanistic account of the anxiety–performance relationship. *International Review of Sport and Exercise Psychology, 1*(2), 184-201. doi:10.1080/17509840802400787

Wilson, M. R., & Pearcy, R. C. (2009). Visuomotor control of straight and breaking golf putts. *Perceptual and Motor Skills, 109*(2), 555-562. doi:10.2466/pms.109.2.555-562

Wilson, M. R., Smith, N. C., Chattington, M., Ford, M., & Marple-Horvat, D. E. (2006). The role of effort in moderating the anxiety - performance relationship: Testing the prediction of processing efficiency theory in simulated rally driving. *Journal of Sports Sciences, 24*(11), 1223-1233. doi:10.1080/02640410500497667

Wilson, M. R., Vine, S. J., & Wood, G. (2009). The influence of anxiety on visual attentional control in basketball free throw shooting. *Journal of Sport and Exercise Psychology, 31*(2), 152-168. doi:10.1123/jsep.31.2.152

Wilson, M. R., Wood, G., & Vine, S. J. (2009). Anxiety, attentional control, and performance impairment in penalty kicks. *Journal of Sport and Exercise Psychology, 31*(6), 761-775. doi:10.1123/jsep.31.6.761

Winter, D. A. (2009). *Biomechanics and motor control of human movement* John Wiley & Sons.

Wood, G., & Wilson, M. R. (2010). A moving goalkeeper distracts penalty takers and impairs shooting accuracy. *Journal of Sports Sciences, 28*(9), 937-946. doi:10.1080/02640414.2010.495995

Woodman, T., & Hardy, L. (2003). The relative impact of cognitive anxiety and self-confidence upon sport performance: A meta-analysis. *Journal of Sports Sciences, 21*(6), 443-457. doi:10.1080/0264041031000101809

Wüst, S., Federenko, I. S., van Rossum, Koper, J. W., & Hellhammer, D. H. (2005). Habituation of cortisol responses to repeated psychosocial stress—further characterization and impact of genetic factors. *Psychoneuroendocrinology, 30*(2), 199-211. doi:10.1016/j.psyneuen.2004.07.002

Yerkes, R. M., & Dodson, J. D. (1908). The relation of strength of stimulus to rapidity of habit-formation. *Journal of Comparative Neurology and Psychology, 18*(5), 459-482. doi:10.1002/cne.920180503

Yuan, Y., & Cheng, P. (2008). The use of salivary cortisol for measuring stress experienced by athletes in the laboratory and field settings. *Sport and Exercise Psychology Research Advances,* , 235-249.

Appendices

Appendix 1: Example of search strategy used in meta-analysis

Example search history pubmed

Search History Medline via pubmed (26-10-2015)			
Search	Query	Items found	Time
#4	Search (#1 AND #2 AND #3)	826	10:01:24
#3	Search (sport OR athlet* OR match OR competition)	341409	10:01:05
#2	Search (Anxiety OR stress OR arousal)	883659	10:00:19
#1	Search (hydrocortisone OR cortisol)	86305	09:59:58

Appendix 2: Matlab script used to analysis kinematic data of club head

Matlab script used for the filtering and calculation of movement execution variables from the x, y and z positional data of the Codamotion markers.

```
close all;
clear all;
files = dir( '*txt'); %nr of files %FILENAMES SHOULD CARRY A NR ORDER (file1
nfiles= length(files);
N = {files.name};

for k = 1:length(files)
    filename = files(k).name
        data = dlmread(filename, '', 5, 0);
 tst = input ('start point');
        t = data(:,1);
x1 = data(tst:end ,6);% reads column 8 from the text file, this needs to be
amended when data is in other columns
y1 = data(tst:end,7);% reads column 9 from the text file, this needs to be
amended when data is in other columns
z1 = data(tst:end,8);% reads column 10 from the text file, this needs to be
amended when data is in other columns
x2 = data(tst:end,2);% reads column 11 from the text file, this needs to be
amended when data is in other columns
y2 = data(tst:end,3);% reads column 12 from the text file, this needs to be
amended when data is in other columns
z2 = data(tst:end,4);% reads column 13 from the text file, this needs to be
amended when data is in other columns

%filtering of data butterworth; clarify cutoff see testresidual for further
%analysis
cutoff =12;
samplerate = 1/(t(2)-t(1))% % identifies sample rate from raw data
wn = cutoff/(samplerate/2);
[B,A] = butter(2, wn);
x1_filt = filtfilt(B,A,x1);
x2_filt = filtfilt(B,A,x2);
```

```
y1_filt = filtfilt(B,A,y1);
y2_filt = filtfilt(B,A,y2);
z1_filt = filtfilt(B,A,z1);
z2_filt = filtfilt(B,A,z2);

meanx = (x1_filt + x2_filt)/2; % calculates the mean position of x from the
two markers
meany = (y1_filt + y2_filt)/2; % calculates the mean y position from the two
markers
meanz = (z1_filt + z2_filt)/2; % calculates the mean z position from the two
markers

diffx = diff(meanx); % calculates the difference in x position from
sequential time steps
velocityx = (diffx/(1/samplerate))/1000; %0.0025 is the 400hz sampling rate,
1000 to change from mm to meter/second
diffvelocityx = diff(velocityx); %calculates the differece in velocityx from
seuqential time steps
acclx = (diffvelocityx/(1/samplerate)); %accelerattion in x direction

diffy = diff(meany);
velocityy = (diffy/(1/samplerate))/1000; %1000 to change from mm to
meter/second
diffvelocityy = diff(velocityy); %calculates the differece in velocityy from
seuqential time steps
accly = (diffvelocityy/(1/samplerate)); %accelerattion in y direction

diffz = diff(meanz);
velocityz = (diffz/(1/samplerate))/1000; % 1000 to change from mm to
meter/second
diffvelocityz = diff(velocityz); %calculates the differece in velocityz from
seuqential time steps
acclz = (diffvelocityz/(1/samplerate)); %accelerattion in z direction

smoothx1 = smooth(meanx, 50); % smooth data with a 50 point moving average
diffx1 = diff(smoothx1); % calculates the difference in x position from
sequential time steps
velocityx1 = (diffx1/(1/samplerate))/1000; %0.0025 is the 400hz sampling
rate, 1000 to change from mm to meter/second
%smoothvelocityx1 = smooth(velocityx1, 50)
diffvelocityx1 = diff(velocityx1);
acclx1 = (diffvelocityx1/(1/samplerate));
%smoothacclx1 = smooth(acclx1, 50)

%calculation of speed and acceleration of raw data
meanx2 = (x1 +x2)/2; %for comparison to check butterworth filtering method
diffx2 = diff(meanx2); %to check butterworth filtering method
velocityx2 = (diffx2/(1/samplerate))/1000; %to check filtering method
diffvelocityx2 = diff(velocityx2); %to check fitering method
acclx2 = (diffvelocityx2/(1/samplerate)); % to check filtering method

initiation = meanx(find(velocityx <-0.05)); % find movement initiation based
on a speed in x direction smaller then -0.05 m/s2
startmovementxposition = initiation(1); %x position of start of movement is
first element of initiationx
startmovement = t(find(velocityx <-0.05));
startmovementtime = startmovement(1);

meanxscaled = meanx(1:end-1);%make lenght meanx similar to velocityx
tscaled = t(1:end-1); %make length t similar to velocityx
```

```
timemoving = tscaled(find(meanxscaled >= startmovementxposition & velocityx
>= 0.05));%as above
ballcontacttime = timemoving(1); %this is the time at ball impact

%finding the vector elements for analyse is the time from startmovementtime
%to ballcontact
movement = find(tscaled >= startmovementtime & tscaled <=ballcontacttime);
length(movement);

timevectormovement = tscaled(movement);
xputt = meanx(movement);

%define backswing and downswing x positions and times
maxxpoint = min(xputt);
ballcontactx = xputt(end);
timestartdownswing = timevectormovement(find(xputt == maxxpoint));

% define the last 25% of the downswing
vectordownswing    =    find(tscaled    >=timestartdownswing    &    tscaled
<=ballcontacttime);
lastquarterdownswing = (length(vectordownswing))/4;
vectorlastquarterdownswing              =              vectordownswing((end-
lastquarterdownswing):end);

% x velocity calculations
xvelocityputt = velocityx(movement);
xvelocityds  =  xvelocityputt(find(timevectormovement  >=timestartdownswing  &
timevectormovement <=ballcontacttime));
unfilteredvelocityxputt = velocityx2(movement);

% y velocity calculations
yvelocityputt = velocityy(movement);
yvelocityds  =  yvelocityputt(find(timevectormovement  >=timestartdownswing  &
timevectormovement <=ballcontacttime));

% z velocity calculations
zvelocityputt = velocityz(movement);
zvelocityds  =  zvelocityputt(find(timevectormovement  >=timestartdownswing  &
timevectormovement <=ballcontacttime));

% x acceleration calculations
xacclputt = acclx(movement);
xacclputtds   =   xacclputt(find(timevectormovement   >=timestartdownswing   &
timevectormovement <=ballcontacttime));
unfilteredacclxputt = acclx2(movement); %rawdata acceleration movement

% y acceleration calculations
yacclputt = accly(movement);
yacclputtds   =   yacclputt(find(timevectormovement   >=timestartdownswing   &
timevectormovement <=ballcontacttime));

% z acceleration calculations
zacclputt = acclz(movement);
zacclputtds   =   zacclputt(find(timevectormovement   >=timestartdownswing   &
timevectormovement <=ballcontacttime));

% angles
clubheadx = x2_filt - x1_filt;
clubheady = y1_filt - y2_filt;
clubheadangle = mod(atan2(clubheadx, clubheady),2*pi)*180/pi;
clubheadangle(clubheadangle<180)=360+clubheadangle(clubheadangle<180);
```

```
clubheadangle = clubheadangle-180;
clubheadangleputt = clubheadangle(movement);
clubheadangledownswing = clubheadangleputt(find(timevectormovement
>=timestartdownswing & timevectormovement <=ballcontacttime)); % this
createds new vectore of angle during the downswing
length(clubheadangledownswing);

%characteristics of data file
ymarkerpositions = (y1_filt(movement))- (y2_filt(movement)); % this needs to
be positive otherwise angle is incorrect
length(ymarkerpositions);
ymarkerdistance = mean(ymarkerpositions);% this needs to be positive
otherwise angle is incorrect

%to check figures
figure; plot(xputt, 'r')
hold on
plot(meanx, 'b')
title(filename)

%data to export and analyse
%time data
totalexecutiontime = ballcontacttime-startmovementtime; %time to complete
the putt
timefordownswing = ballcontacttime - timestartdownswing; % time takes for
downswing
timeforbackswing = timestartdownswing - startmovementtime; % time taken for
backswing
ratioBS_DS = (timefordownswing/timeforbackswing);
%distances
backswinglengthx = abs(maxxpoint - ballcontactx); % length of backswing x
%velocity
xvelocityimpact = xvelocityds(end);
averagexvelocityds = mean(xvelocityds);
stdevxvelocityds = std(xvelocityds);
stdevxvelocity25ds = std(velocityx(vectorlastquarterdownswing));
averagexvelocity25ds = mean(velocityx(vectorlastquarterdownswing));

yvelocityimpact = yvelocityds(end);
averageyvelocityds = mean(yvelocityds);
stdevyvelocityds = std(yvelocityds);
stdevyvelocity25ds = std(velocityy(vectorlastquarterdownswing));
averagexyvelocity25ds = mean(velocityy(vectorlastquarterdownswing));

zvelocityimpact = zvelocityds(end);
averagezvelocityds = mean(zvelocityds);
stdevzvelocityds = std(zvelocityds);
stdevzvelocity25ds = std(velocityz(vectorlastquarterdownswing));
averagezvelocity25ds = mean(velocityz(vectorlastquarterdownswing));

%acceleration
xacclimpact = xacclputtds(end);
averagexacclds = mean(xacclputtds) ;
stdevxacclds = std(xacclputtds);
stdevxaccl25ds = std(acclx(vectorlastquarterdownswing));
averagexaccl25ds = mean(acclx(vectorlastquarterdownswing));

yacclimpact = yacclputtds(end);
averageyacclds = mean(yacclputtds) ;
stdevyacclds = std(yacclputtds);
stdevyaccl25ds = std(accly(vectorlastquarterdownswing));
```

```
averageyaccl25ds = mean(accly(vectorlastquarterdownswing));

zacclimpact = zacclputtds(end);
averagezacclds = mean(zacclputtds);
stdevzacclds = std(zacclputtds);
stdevzaccl25ds = std(acclz(vectorlastquarterdownswing));
averagezaccl25ds = mean(acclz(vectorlastquarterdownswing));

%angles
anglestartdownswing = clubheadangleputt(1);
impactangle = clubheadangleputt(end); % angle at impact
stdevangledownswing   =   std(clubheadangledownswing);   %   stdev   from   the
downswing
stdevangledownswing25    =    std(clubheadangle(vectorlastquarterdownswing));
%stdev of the putt angle in the last 25% of the downswing

%trialname = ask(1:end); % get complete filename (includes the .txt)
trialname1 = strtok(filename,'.'); % removes the .txt from the filename.
filenames{k} = trialname1;
variablenames   =   {'filename'   'totalexecutiontime',   'timefordownswing',
'timeforbackswing',  'ratioBS_DS',  'backswinglengthx',  'xvelocityimpact',
'averagexvelocityds',         'stdevxvelocityds',         'yvelocityimpact',
'averageyvelocityds',         'stdevyvelocityds',         'zvelocityimpact',
'averagezvelocityds', 'stdevzvelocityds', 'xacclimpact', 'averagexacclds',
'stdevxacclds',     'yacclimpact',     'averageyacclds',     'stdevyacclds',
'zacclimpact',  'averagezacclds',  'stdevzacclds',  'anglestartdownswing',
'impactangle', 'stdevangledownswing'};
outputvector{k}        =vertcat(totalexecutiontime,        timefordownswing,
timeforbackswing,     ratioBS_DS,     backswinglengthx,     xvelocityimpact,
averagexvelocityds, stdevxvelocityds,  yvelocityimpact, averageyvelocityds,
stdevyvelocityds,   zvelocityimpact,  averagezvelocityds,  stdevzvelocityds,
xacclimpact,  averagexacclds,  stdevxacclds,  yacclimpact,  averageyacclds,
stdevyacclds,       zacclimpact,       averagezacclds,       stdevzacclds,
anglestartdownswing, impactangle, stdevangledownswing);
end

pp = num2cell([outputvector{:}]);
ss = filenames;

datatowrite = vertcat(ss, pp);
datatowrite1 = horzcat(variablenames', datatowrite)';
xlswrite('test1.xls', datatowrite1)
```

Appendix 3: Matlab script to process raw text files of eye tracking analysis

Example of a Matlab script used for the analysis of raw text files produced from the frame-by-frame analysis of visual search behaviour.

```
%XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
% This file imports and analyses the data from the text files that have
% been created using the Begaze eyetracking software.
% It analyzes the gathered data, calculating various variables regarding
% the measured gaze behaviour and the areas of interest (aoi) that were
% included in the Begaze analysis.
%
% The aois used in the analysis have to be put into this program in the
% aoisss cell array. These aois need to be put in exactly as they are
% defined in the Begaze software.
%
% If possible use the STIMULUS defined in Begaze, if they are different for
% each participant and each trial. Otherwise use the filenames. This can be
% changed at the bottom of the program.
%
% The variables calculated will be (in order of appearance in the excel
% file): name(variable): what it is
% -stimulus(stimulus: name for each row of data
% -time(totaltime): total time (in s) for each trial
% -scanrate dwells: nr of dwells per second
% -scanratefix: number of fixations per second
% -totalnrdwells(nrdwells): total number of seperate dwells that were made
% -totalnrfix(totnrfix): total number of fixations that were made
% -nrfixloc(fixloc): number of fixation locations
% -nr"aoi"(m): number of frames each aoi was attended to during the trial
% -nrdwells"aoi"(dwellaoi): number of seperate dwells on each aoi
% -%"aoi"(percentage1): percentage of total trial time each aoi is attended
to
% -time"aoi"(timeAOI): time (s) each aoi is attended to
% -nrfix"aoi"(counts1m): number of fixations on each aoi
% -relnrfix"aoi" (relfix): the relative number of fixations on each aoi
% -totfixtime"aoi"(ftimetotAOI): total fixation time (in s) on each aoi
% -avfix"aoi"(avfixlength): average length (in s) of the fixations on each
aoi
% -%fix"aoi"(fpercentage): percentage of total trial time each aoi is fixated
on
%XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
clear all
close all
clc
% aoisss needs to include all areas of interest as they are defined in
% Begaze. There can not be spaces in the labels of the aoisss.NoFix


aoisss = {'ball' 'hole' 'saccade' 'block1' 'block2' 'qe' 'green' 'club'
'other' 'gap' 'drift'};
vectors = {'stimulus' 'time' 'totalnrdwells' 'nrdwellloc' 'scanratedwell'
'totalnrfix' 'nrfixloc' 'scanratefix' 'nrtarget' 'nrball1' 'nrblock'
'relnrtarget' 'relnrball1' 'relnrblock' 'perctarget' 'percball1' 'percblock'
'timetarget' 'timeball1' 'timeblock'}'; %'stimulus' 'time' 'totalnrdwells'
'nrdwellloc' 'scanratedwell' 'totalnrfix' 'nrfixloc' 'scanratefix'}';
names = {'nrdwells' 'perc' 'time' 'relnrdwell' 'avdwell' 'nrfix' 'relnrfix'
'totfixtime' 'avfix' 'percfix'}';
j = 1;
for i = 1:length(names)
    pn{i} = strcat(names(i), aoisss);
    pln(j,:) = pn{1,i};
    j = j+4;
end
pln = pln';
placenames = pln(~cellfun('isempty',pln));
```

```
vectornames = vertcat(vectors, placenames);

files = dir( '*txt'); %nr of files %FILENAMES SHOULD CARRY A NR ORDER (file1
file2
nfiles= length(files);
h = 34; %number of headerlines
framerate = 30;

eln = 10;
linenames = '';

for kk = 1:length(files)
    fid = fopen([files(kk).name], 'rt');
    if (fid < 0)
        printf('ERROR: could not open file\n')
    else
        n = 0;
        while ~feof(fid)
            n = n+1;
            if (n ~= eln)
                fgetl(fid);
            else
                linenames{kk} = fgetl(fid);
            end
        end
        fclose(fid);
    end
end
stimulus = regexprep(linenames, '## Stimulus:', ''); %Name for each column
of the final file.
for k = 1:length(files)
    fid = fopen([files(k).name], 'rt');
    if (fid < 0)
        printf('ERROR: could not open file\n')
    else
        mydata(k)                          =                      textscan(fid,
'%*s%*s%*s%*s%*s%*s%*s%*s%*s%*s%*s%*s%*s%*s%*s%s%*s%*[^\n]', 'headerlines',
h);
        filenames{k} = [files(k).name];
    end
    fclose(fid);
end
lenghtmydata = length(mydata);
for z = 1:lenghtmydata
    s = mydata{z};
    %s = strrep(s10, 'block2', 'block1');
    s(any(cellfun(@(x)x(1)=='-', s),2), :) = [];%this removes the character
'-' from the data file
    s = s(cellfun(@(s)isempty(regexp(s,'Start')),s));
    [~,ii] = ismember(s(1:end),aoisss);
    counts = histc(ii, 1:numel(aoisss));
    m = num2cell(counts); % m is frequency of AOIs.
    percentage = (counts/length(s))*100;
    percentage1 = num2cell(percentage); % dwellpercentage of AOI
    frametime = 1/framerate; % calculates the time of 1 frame
    timeAOIsss = counts*frametime; % calculates the time spent at the AOIs
    timeAOI =num2cell(timeAOIsss);


    % time to complete the trial
```

```
    totaltime{z}  =  length(s)*frametime;  %calculates  the  time  taken  to
complete the trial

    % Calculating the number of dwells.
    i1 = ii > 0;
    dw1 = s(i1,:);
    dw2 = dw1([true(1);diff(ii(i1))~=0],:);
    dwocc               =              strcmpi(dw2(:,ones(1,length(aoisss))),
aoisss(ones(length(dw2),1),:));
    counts1dw =sum(dwocc,1);
    dwellaoi = num2cell(counts1dw)'; %number of times each aoi is attended
too.
    dwells = [true(1);diff(ii(i1))~=0];
    nrdwells = sum(dwells); %total number of dwells in the trial.


    % Calculating the number of fixations on each AOI.
    % The loop below transforms all the aois that were only attended for 1
    % or 2 frames into 0's.
    constantVar = s(1);
    counter = 1;
    for i = 2:length(s)
        tempVar = s(i);
        if (strcmp(tempVar, constantVar) == 1)
            counter = counter+1;
        else
            if (counter <= 2)
                lowerLimit = i-counter;
                upperLimit = i-1;
                ii(lowerLimit:upperLimit) = 0;
            end
            counter = 1;
            constantVar = s(i);
        end
    end
    if (counter <= 2)
        lowerLimit = length(s) - counter + 1;
        upperLimit = length(s);
        ii(lowerLimit:upperLimit)=0;
    end
    % Creating a cellarray with 0's instead of the aoi's that were only
    % attended to for 1 or 2 frames.
    for j = 1:length(ii)
        if (ii(j) == 0)
            r{j} = '0';
        else
            r{j} = s{j};
        end
    end
    rr = r';

    out = rr([true(1);diff(ii)~=0 ],:);
    out(any(cellfun(@(x)x(1)=='0', out),2), :) = []; % Gives a vector of all
the times that an AOI was attended to for more than 1 or 2 frames
    occurences            =            strcmpi(out(:,ones(1,length(aoisss))),
aoisss(ones(length(out),1),:));
    counts1 =sum(occurences,1); % Number of seperate fixations that each AOI
is attended to. Fixations are 3+ frames on the same aoi.
    counts1m = num2cell(counts1);
    fixloc = 0; % Number of locations that a participant focussed on.
    for i = 1:length(counts1)
```

```
        if counts1(i) > 0
            fixloc = fixloc + 1;
        end
    end

    dwellloc = 0;
    for i = 1:length(counts1dw)
        if counts1dw(i) > 0
            dwellloc = dwellloc + 1;
        end
    end

    %write a horizontal row of the scanpath for each loop of z in scanpath.xls
    %x = dw2';
    %my_cell = sprintf( 'A%s',num2str(z) );
    %xlswrite('scanpath.xls',x,1,my_cell);

    totnrfix = sum(counts1); % Total number of fixations that were made over
all the aois.
    scanratefix = totnrfix/(length(s)*frametime); %scanrate for fixations
    scanratedwell = nrdwells/(length(s)*frametime); %scanrate for dwells
    totfix{z} = vertcat(nrdwells, dwellloc, scanratedwell, totnrfix, fixloc,
scanratefix);


    % Calculating times and percentages for only those frames that were
    % included in fixations.
    fcounts = histc(ii, 1:numel(aoisss)); % Total number of frames for the
fixations on each AOI
    ftimetotAOI = fcounts*frametime; % Total fixation time on each AOI
    fpercentage = (fcounts/length(s))*100; % Percentage of total time that
was spent fixating on each AOI

    % Average length of fixations
    avfixlength  =  ftimetotAOI./counts1';  %  This  provides  the  average
length(s) of a fixation at the respetctive AOI
    avfixlength(isnan(avfixlength)) = 0; % Replaces NaN with 0
    %avfix{z} = vertcat(ftimetotAOI, avfixlength, fpercentage);

    % average dwell length
    avdwelllength =  timeAOIsss./counts1dw';
    avdwelllength(isnan(avdwelllength)) = 0;
    avdwelllength = num2cell(avdwelllength);
    % Relative number of fixations
    relfix  =  (counts1  /  totnrfix)*100;  %  Relative  number  of  fixations  on
each AOI.

    relnrdwells = (counts1dw / nrdwells)*100;
    relnrdwells = num2cell(relnrdwells);
    relnrdwells = relnrdwells';

    relnrdwelltarget  =  relnrdwells{2}  +  relnrdwells{10};%  sums  relnrdwells
of variable 1 and 10 hole and gap
    relnrdwellball1 = relnrdwells{1} + relnrdwells{6}; % sums relnrdwells of
variable 1 and 10 ball and QE
    relnrdwellblock = relnrdwells{4} + relnrdwells{5}; %sums relnrdwell of
variable block1 and block2

    dwelltarget = dwellaoi{2} + dwellaoi{10};% sums nrdwells of variable 1
and 10 hole and gap
```

```
    dwellball1 = dwellaoi{1} + dwellaoi{6}; % sums nrdwells of variable 1 
and 10 ball and QE
    dwellblock = dwellaoi{4} + dwellaoi{5}; %sums nrdwell of variable block1 
and block2

    perctarget = percentage1{2} + percentage1{10};% sums %dwell time of 
variable 1 and 10 hole and gap
    percball1 = percentage1{1} + percentage1{6}; % sums %dwell time of 
variable 1 and 10 ball and QE
    percblock = percentage1{4} + percentage1{5}; % sums %dwell time of 
variable block1 and block2

    timetarget = timeAOI{2} + timeAOI{10};% sums dwell time of variable 1 
and 10 hole and gap
    timeball1 = timeAOI{1} + timeAOI{6}; % sums dwell time of variable 1 and 
10 ball and QE
    timeblock = timeAOI{4} + timeAOI{5}; % sums dwell time of variable block1 
and block2

    %'stimulus' 'time' 'totalnrdwells' 'nrdwellloc' 'scanratedwell' 
'totalnrfix' 'nrfixloc' 'scanratefix' 'nrtarget' 'nrball1' 'nrblock' 
'relnrtarget' 'relnrball1' 'relnrblock' 'perctarget' 'percball1' 'percblock' 
'timetarget' 'timeball1' 'timeblock'
    mergedaoi{z} = vertcat(dwelltarget, dwellball1, dwellblock, 
relnrdwelltarget, relnrdwellball1, relnrdwellblock, perctarget, percball1, 
percblock, timetarget, timeball1, timeblock);
    %'nr' 'nrdwells' 'perc' 'time' 'relnrdwell' 'avdwell' 'nrfix' 'relnrfix' 
'totfixtime' 'avfix' 'percfix'
    % Matrix containing total fixation time on each AOI, average fixation
    % time on each AOI, percentage of trial time that was fixated on each 
AOI and the relative number of fixations.
    resultAOI{z} = vertcat(dwellaoi, percentage1, timeAOI, relnrdwells, 
avdwelllength, counts1m');
    avfix{z} = vertcat(relfix', ftimetotAOI, avfixlength, fpercentage);
end
ddd = totaltime;
ppp = num2cell([totfix{:}]);
rrr = num2cell([mergedaoi{:}]);
ttt = [resultAOI{:}];
qqq = num2cell([avfix{:}]);
sss = stimulus;
%sss = filenames;

datatowrite = vertcat(sss, ddd, ppp, rrr, ttt, qqq);
output = horzcat(vectornames, datatowrite)';

xlswrite('DataBegaze.xlsx', output)
```

Appendix 4: The amended version of the CAT-Sport

How athletes approach competition may vary considerably and THERE ARE NO RIGHT OR WRONG ANSWERS. The following sentences may or may not be relevant to you, but following the completion of the golf putting task, please select the most appropriate response FOR YOU in relation to each of the statements below.
Please answer ALL statements.

I am worried that I said or did the wrong things					
Totally Disagree	Rather Disagree	Disagree to some extent	Agree to some extent	Rather Agree	Totally Agree
I am worried about the kind of impression I made					
Totally Disagree	Rather Disagree	Disagree to some extent	Agree to some extent	Rather Agree	Totally Agree
I am concerned that others find fault with me					
Totally Disagree	Rather Disagree	Disagree to some extent	Agree to some extent	Rather Agree	Totally Agree
I expected that I would achieve success rather than experience failure					
Totally Disagree	Rather Disagree	Disagree to some extent	Agree to some extent	Rather Agree	Totally Agree
I looked forward to the rewards and benefits of the potential success					
Totally Disagree	Rather Disagree	Disagree to some extent	Agree to some extent	Rather Agree	Totally Agree
I was concerned what other people would think of me					
Totally Disagree	Rather Disagree	Disagree to some extent	Agree to some extent	Rather Agree	Totally Agree
The challenging situation motivated me to increase my efforts					
Totally Disagree	Rather Disagree	Disagree to some extent	Agree to some extent	Rather Agree	Totally Agree
I thought to be successful in this task rather than expecting to fail					
Totally Disagree	Rather Disagree	Disagree to some extent	Agree to some extent	Rather Agree	Totally Agree
I worried what other people would think of me, even though it didn’t make any difference					
Totally Disagree	Rather Disagree	Disagree to some extent	Agree to some extent	Rather Agree	Totally Agree
I am looked forward to the opportunity to test my skills and abilities					
Totally Disagree	Rather Disagree	Disagree to some extent	Agree to some extent	Rather Agree	Totally Agree
I was worried about what other people were thinking of me					
Totally Disagree	Rather Disagree	Disagree to some extent	Agree to some extent	Rather Agree	Totally Agree
I feel like this task was a Threat					
Totally Disagree	Rather Disagree	Disagree to some extent	Agree to some extent	Rather Agree	Totally Agree