The Effects of Attentional Load and Anxiety on Aiming Task Performance in Sport

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Contents

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List of Abbreviations

ACT	Attentional Control Theory
CA	Cognitive Anxiety
CLT	Cognitive Load Theory
GIR	Green in Regulation
ME	Mental Effort
MRF-3	Mental Readiness Form
PET	Processing Efficiency Theory
PGA	Professional Golfers Association
QE	Quiet Eye
QED	Quiet Eye Duration
QEHA	Quiet Eye High Attention
QELA	Quiet Eye Low Attention
QET	Quiet Eye Training
RSME	Rating Scale for Mental Effort
SA	Somatic Anxiety
SC	Self Confidence
SD	Standard Deviation
SGU	Scottish Golf Union
TT	Technical Training

List of Figures

List of Tables

Abstract

The mechanisms underpinning perceptual-cognitive skills during performance in aiming tasks were examined in the current thesis. Firstly, due to a lack of research within the area, Chapter two investigated expertise differences and the effect of task complexity on visual search behaviours, movement kinematics during golf short game shots. Near experts were found to exhibit a significantly longer total quiet eye duration (QED) than the expert group during the putting task; a difference underpinned by having a QE-pre duration of more than double that of the experts. Task complexity had no significant effect on total QED but during a perceived harder task, QE-pre was again shown to be a distinguishing factor. Using the results of Chapter 2, Chapter 3 aimed to investigate the effects of increased attentional workload on the perceptual-cognitive skills and performance of expert and novice basketballers. Specifically, the aim of the chapter was to investigate whether increased attentional load through the use of a dual-task paradigm, exhibited the same negative effects as an increase in anxiety. QED was found to be lower during high attention conditions than low attention conditions, suggesting that processing efficiency was effected by the increased cognitive stress. Therefore, using the results of the two previous chapters, Chapter 4 aimed to investigate whether QE training under high attentional load could protect individuals somewhat from the negative effects of increased anxiety when performing under pressure in competition. It was found that both QE training groups increased their QED from pre-test to retention, however during a high attention post-test, only the QE high attention trained group maintained their QED's when compared to QE low attention and technical trained groups. The findings have major implications for both theory and practice, whilst extending the research in the area of perceptual-cognitive skills.

Chapter 1: Review of Expertise

and Perceptual-Cognitive Skills in Sport

To be held in reverence by your peers and admired for your expertise is generally considered the pinnacle of your career; no environment is this truer than in sport. Sporting expertise has long been characterised by the ability of a performer to consistently demonstrate superior athletic ability (Janelle & Hillman, 2003). However, although some individuals may be born with a certain natural predisposition which facilitates the attainment of expertise (Baker & Horton, 2004), researchers have identified the importance of many thousands of hours of task-specific practice (Ericsson, Krampe, & Tesch-Römer, 1993). Through two over-arching mechanisms: accumulation of experience and repetitive execution of domain-specific actions, an individual was thought to develop their sporting prowess. More recently, the development of expertise has been further linked to a conscious effort by the individual to engage in deliberate practice, whereby there are provisions for immediate feedback, problem solving and evaluation of performance (Ericsson, 2008). It is during this deliberate practice that performers are thought to refine the physical motor skills, but also the perceptual-cognitive skills, needed for expert performance in sport (Broadbent, Causer, Ford, & Williams, 2015).

Perceptual-cognitive skills denote an individual's ability to use their senses, mainly the sense of sight, to perceive and process information from their surroundings. This information is then combined with previous knowledge and experience of similar situations in order to make an informed decision and select an appropriate response (Marteniuk, 1976). Therefore, if by establishing training methods that incorporate the development of perceptual-cognitive skills as well as the more externally observed motor skills, an individual has a greater chance of achieving expertise in their field. Further, when participating in sporting competition, and more so as the standard of competition rises, individuals can experience large amounts of anxiety coupled with an increase in attentional demand due to potentially distracting stimuli. This may affect the way they perceive, interpret and use information from their environment and thus in turn influence performance. This thesis therefore aims to investigate the perceptual-cognitive antecedents of expertise in sport by studying expert and novice performers in various anxiety-inducing and attention-manipulating scenarios. Further to this, a novel method of training perceptual-cognitive skills under high attentional load with the aim of improving skill acquisition and performance under pressure will be examined. This introductory chapter provides an overview of the perceptual-cognitive expertise literature, current models of anxiety and performance, a review of the current perceptual-cognitive skills training research and the rationale for the current thesis.

Expert Performance Approach

Expertise in sport is characterised by more successful and consistent performance over a sustained period (Marteniuk, 1976). To identify any perceptual-cognitive attributes that may assist in this higher level of performance, researchers have mainly investigated the variances between expert and novice populations. Although human history is littered with tales of experts across an array of different fields, it wasn't until the mid-twentieth century that efforts began to try and understand what processes underpinned this expertise.

One of the first to employ such an approach was De Groot (1965) who investigated differences in the cognitive processes of both chess masters and lesser-skilled players. Using a talk-aloud protocol, De Groot (1965) was able to analyse players thought processes as they decided upon their next moves. However, the authors failed to find any significant differences in thought processes of the two skill groups that would suggest why experts were more likely to pick the correct move. Nevertheless, De Groot (1965) continued investigating skill-based differences in the ability to recall and reproduce a hypothetical chess board under temporal pressures. It was found that chess masters could reproduce the board almost perfectly, whereas the lesser-skilled players could only recall three to four positions. De Groot (1965) concluded that through the accumulation of experience, chess masters were better able to retrieve significant strategic information about the scenario presented from their long-term memory.

Further investigation into the cognitive processes underlying expert performance led to Chase and Simon (1973) to replicate the findings of De Groot (1965) that expert chess players were better able to recall match play scenarios presented on the board than lesser-skilled players. However, it was identified that this increased ability to recall and reproduce piece positions disappeared when random non-match play scenarios were presented. Chase and Simon (1973) concluded, in accordance with De Groot (1965), that this superior ability to recall patterns of match play but not random sequences was due to a more extensive knowledge of possible match scenarios coupled with an ability to rapidly access and efficiently retrieve this task-specific knowledge from memory. Furthermore, similar findings have been reproduced across a number of different fields including soccer (Williams & Davids, 1995), medicine (Patel & Groen, 1991) and computer programming (Vessey, 1987).

Although studies such as De Groot (1965) and Chase and Simon (1973) set out early explanations of differences in expertise, it was Ericsson and Smith (1991) who challenged the limitations of these studies. They argued that instead of being restricted by the fixed limits of short-term memory, experts learn complex skills that enable them to change the perceived limits of working memory. This enables experts to rapidly encode information in long-term memory with selective access when required, allowing them to free-up resources in working memory that can be used for other task demands needed for increased performance. As a consequence of these differing views Ericsson and Smith (1991) devised their own framework, namely the expert performance approach (see Figure 1.1).

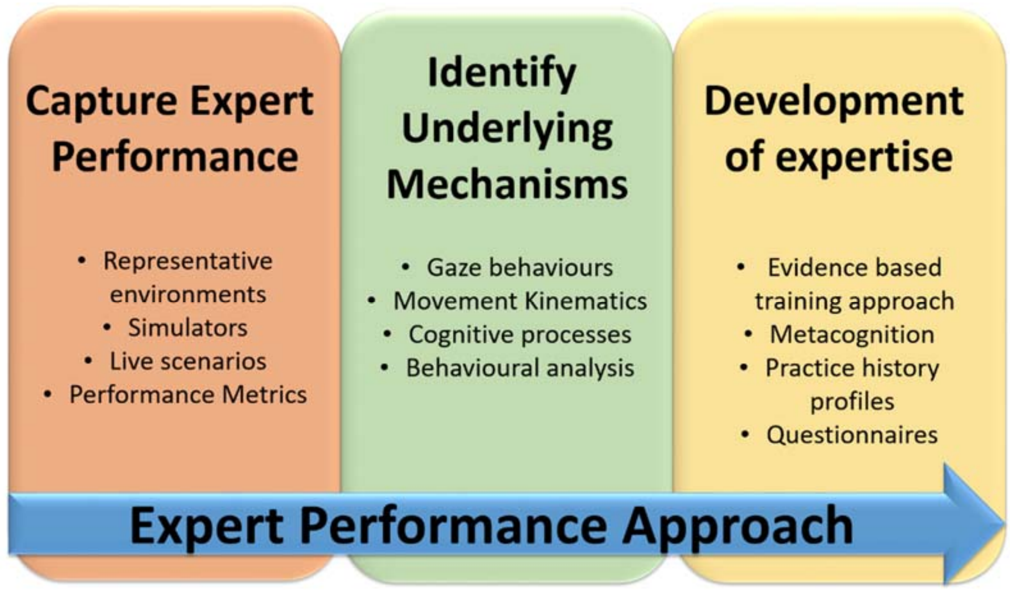

Figure 1.1. The Expert Performance Approach, adapted from Ericsson and Starkes (2003)

Through three stages, the expert performance approach aims to use empirical methods to identify systematic differences in skill levels between performers. These stages start with the observation of the skill *in situ*, from which representative tasks can be designed that allow the skill to be reproduced in a controlled environment. Next, the underlying mechanisms associated with expert or increased performance must be determined; this is typically done by recording process-tracing measures such as eye movements and verbal reports during performance of the representative tasks. The final stage aims to identify the processes by which expertise was developed so that practice methods or instructions can be adapted to allow the expedition of expertise acquisition. As the expert performance approach is concerned with identifying the processes and underlying mechanisms that differentiate performance in various skill-levels, the use of the approach has allowed a plethora of studies to be undertaken in the field of perceptual-cognitive skills in sport.

Expertise differences in Perceptual-Cognitive Skills

Perceptual-cognitive skill is the ability to identify and acquire environmental information for incorporation with existing knowledge such that appropriate responses can be formulated and executed (Marteniuk, 1976). These skills are crucial to the execution of goal-directed actions and thus are a vital part of expertise in domains such as medicine (Causer, Barach, & Williams, 2014), law enforcement (Vickers & Lewinski, 2011) and sport (Williams & Ericsson, 2005). In higher skilled sportspeople, perceptual-cognitive skills have been found to be more refined and effective during a variety of sporting contexts (Mann, Williams, Ward, & Janelle, 2007).

The ability to recognise patterns of play or performance structure was one of the seminal findings of De Groot (1965) and has since consistently been shown to indicate a higher level of expertise in a number of domains including sport. In soccer, skill-based differences in the recognition of previously viewed dynamic sequences of play has been investigated (North, Williams, Hodges, Ward, & Ericsson, 2009; Williams, North, & Hope, 2012). It was reported that skilled individuals were significantly better able to identify the clips that they had viewed before than their lesser-skilled counterparts. Furthermore, the lesser-skilled participants were unable to distinguish previously viewed clips from those that were presented for the first time. North et al. (2009) suggested that based on the interactive-encoding model (Dittrich, 1999), skilled participants' greater amount of experience within their sport results in them developing a substantial library of encountered scenarios encoded with player motion information and temporal relationships between features in the environment. The skilled players can then evaluate initial information from the current environment and compare this against the database of previously encountered scenarios to identify patterns or structure in play. On the other hand, due to their lack of experience in their sport, the lesser-skilled participants are less able to compare current information to previously encountered situations and thus must rely on identification of distinctive features in the environment.

Not only are skilled performers better able to recognise and recall patterns in their domain more accurately, but through the use of occlusion paradigms, researchers have shown experts to be better able to predict outcomes of sporting situations. By removing visual information before and during ball contact in tennis shots, Abernethy, Gill, Parks, and Packer (2001) found that experts exhibited a superior ability to anticipate ball direction and depth. They concluded that when vision was occluded before ball contact, experts were using situational probabilities and sequential dependencies from their opponent's previous play to accurately predict the outcome of their shots. These findings are consistent with the findings of Murphy, Jackson, and Williams (2018) and (Broadbent, Gredin, Rye, Williams, & Bishop, 2018) who also found that when participants were shown preceding shots, they more accurately predicted shot direction. However, in Abernethy et al. (2001) when vision was occluded during the final shot and in Murphy et al. (2018) when player and ball motion were accessible, experts performed at their best. The authors proposed that this was due to superior pick up of advanced kinematic information.

One of the first studies to identify advanced cue utilisation was Abernethy and Russell (1984) who found that when ball flight was occluded, skilled cricketers were better able to predict where the ball would finish and therefore select an appropriate response more quickly. The authors suggested that this was due to the participants picking up key postural information before ball release. However, without the use of eye tracking technology, this conclusion could not be measured. More recently, advances in eye tracking systems have enabled the role of advanced cues in anticipation to be examined in more depth. With the possibility to record point of gaze to accurately, eye tracking technology has enabled visual search to be recorded in both video based scenarios and in-situ scenarios. Savelsbergh, Williams, van der Kamp, and Ward (2002) examined expertise differences in anticipation of soccer goalkeepers during penalty kicks shown on a computer screen. It was found that experts were better able to predict ball direction than novices and this was associated with a more efficient visual search strategy. Experts fixated more on the kicking leg, non-kicking leg and ball areas whereas novices spent longer fixating the arms, hips and trunk. Further to this, Alder, Ford, Causer, and Williams (2014) through the use of a video screen displaying expert players, examined skill-based differences in the ability to predict badminton serve direction. Again, experts were better able to predict shot direction and this was associated with fixations towards the most discriminating kinematic locations between serve types. The ability of experts to pick up this key advanced information to enhance anticipation and decision-making performance was linked to a more refined and effective overall visual search.

The capability of researchers to track eye-movements during sports performance allows the methods by which individuals scan the environment to be accurately measured. Sport is mostly performed in an environment that is fast paced, dynamic and temporally constrained. Therefore the ability to select the appropriate information from the situation or environment can be crucial in both decision making and anticipation. In soccer, Roca, Ford, McRobert, and Williams (2011) during their first experiment showed that skilled participants were better able to anticipate the next move of the attacking player in possession of the ball, whilst also being better at selecting an appropriate response. It was found that skilled players demonstrated more fixations of shorter duration on significantly more locations than the lesser-skilled players. In doing so, the skilled players were possibly able to identify patterns in the build-up play and/or use player positions to formulate the most likely choice of the player in possession. Further to this, lesser-skilled participants spent significantly longer fixating the player in possession and the movement of the ball, thus they most likely did not pick up spatial cues from the environment which may have informed future actions of the player in possession. These findings were in accordance with previous research in soccer (Williams, Davids, Burwitz, & Williams, 1994), however, a meta-analysis of the literature by Mann et al. (2007) found that experts generally exhibit fewer fixations of longer duration. It is thought that by refining their visual search, experts are able to focus on task-relevant stimuli for longer, thus extracting more information to aid in the improvement of performance (Williams, Davids, & Williams, 1999).

An individual's visual search during sporting competition however is affected by a number of differing factors. As sport can be temporally constrained, the task demands are unique for each different situation an individual may find themselves in and therefore the time they have to decide upon the most relevant stimuli to process may change. Thus, if they are better able to pick out key information from the environment more efficiently, the chances of successful performance are increased. Nevertheless, this increased chance of successful performance is very much dependent on the accessibility and quality of the information available within the environment. If an individual is able to access or perceive the key information easily, they will be able to use this information more readily than if they need to scan several times to find it. Further, if this information is of sufficient quality, i.e. they are able to understand easily what the information means without difficulty, again successful performance is more likely. When the quality of information is reduced such as an opposing player employing a deceptive tactic such as a step over in soccer, the chances of success are reduced (Wright & Jackson, 2014). During anticipation and decision making tasks, due to their dynamic and temporally constrained nature, the ability the use visual search becomes of key importance to make quick and effective decisions. However, the role of the visual system and visual search has also been found to be of key importance during aiming and interceptive tasks with a particular focus on specific individual gaze behaviours.

A significant study for the identification of individual gaze behaviours and their role during sports performance was Vickers (1992). By examining high and low-skilled golfers during 10ft putts, it was found that experts fixated the back of the ball for longer before and during their putting stroke than their lesser-skilled counterparts. Further, the lesser-skilled golfers tended to track the clubhead during movement, whereas the skilled group more consistently held their gaze on the back of the ball throughout. This difference in final fixation duration was found to be a determinant of skill-level and improved accuracy; resulting in subsequent studies investigating whether the final fixation before movement could significantly impact performance quality.

Quiet Eye

Vickers followed up her initial investigation by examining the visual behaviours of elite basketball players during successful and unsuccessful free throws (Vickers, 1996a, 1996b, 1996c). This seminal study found that experts had significantly longer preparation and impulse phases than near-experts, but also exhibited a significantly longer final fixation on the target before initial movement onset. This fixation was termed the Quiet Eye (QE) and defined by Vickers (1996c) as the final fixation or tracking gaze to a specific location or object in the visuomotor workspace within 3 ° of visual angle (or less) for a minimum of 100ms. The QE begins with the onset of the fixation, prior to critical movement initiation, and ends when the gaze deviates from that location. The location and timing of the QE is therefore different depending on the given task. For example in darts, the QE has been defined as the final fixation to the target prior to the extension of the arm (Vickers, Rodrigues, & Edworthy, 2000), whilst it is similarly defined in basketball (Wilson, Vine, & Wood, 2009). However, in golf the QE has been defined as the final fixation towards the back of the ball before initiation of the putting backstroke (Vine, Moore, & Wilson, 2011). A longer QE has been associated with improved performance in a range of sports including shotgun shooting (Causer, Bennett, Holmes, Janelle, & Williams, 2010) biathlon (Vickers & Williams, 2007), golf (Vine et al., 2011), tennis (Singer et al., 1998) and soccer (Wood & Wilson, 2011). In addition, a longer fixation on the target has also been shown to be beneficial during locomotive tasks. Hollands, Patla, and Vickers (2002) reported that before change of direction in a walking task, participants used specific visual behaviours to focus their gaze on the light cue target. Further, Young, Wing, and Hollands (2012) found that higher risk older adults fixated the target for significantly longer on approach than lower risk older adults during both near and far obstacle conditions in a walking task but looked away from the target sooner. This inability to maintain the fixation throughout the whole movement resulted in a poorer stepping performance when attempting to surmount increasingly complex tasks. The benefits of maintaining the QE or final fixation throughout the critical movement have been clearly demonstrated, yet currently, the mechanisms by which the QE exerts its beneficial effects on performance are still relatively unknown (Vickers, 2016). It has been suggested that the QE is a functional representation of the cognitive time needed to pre-program the correct movement parameters for action execution (Vickers, 2011). Further to this, the QE has been associated with increased cortical activation (Mann, Coombes, Mousseau, & Janelle, 2011) and a longer QE has also been associated with more efficient movement kinematics (Causer et al., 2010). However, the pre-programming theory presents just one possible function of the QE, with an online-control function recently being suggested.

In an attempt to understand the mechanism by which the QE works, Vine, Lee, Moore, and Wilson (2013) divided the fixation into specific components; QE-pre (proportion of the QE from onset to movement initiation), QE-online (proportion of the QE from movement initiation to ball contact) and QE-dwell (proportion of the QE from ball contact to fixation deviation). During a golf putting shootout task, it was found that missed putts were associated with shorter durations of both QE-online and QE-dwell components of the final fixation. The authors suggested that this shows the QE serves an online control function due to performance decreasing when attentional focus was not maintained throughout the duration of the critical movement. Further, through the use of an occlusion paradigm during a golf putt, Vine, Lee, Walters-Symons, and Wilson

(2015) reported that occluding vision early (occluded on backswing initiation), resulted in a significant performance decrement when compared to late occlusion of vision (after putter placement until backswing initiation). It was suggested that by returning vision during the putting stroke, the individuals were able to correct any initial mistakes in their movement and ensure a more precise contact with the ball. Additionally, Causer, Hayes, Hooper, and Bennett (2017) also used an occlusion paradigm to investigate the function of the QE. Novice participants, required to putt golf balls to both 6ft and 11ft targets under full-vision or occlusion conditions, displayed significantly higher radial error during both 11ft and occluded conditions. Both were associated with longer QE-pre durations. However, during the full-vision conditions, participants displayed significantly longer QE-online durations than in the occlusion conditions. These findings suggest that the QE serves both a pre-programming and online control function, however, the extent to which both functions elicit their own effects on performance is still largely unknown and needs further research. Despite this lack of understanding, the QE has been shown to be a differentiating factor between successful and less successful performance.

Elite or expert performers have been found to exhibit a longer QE than their lesser-skilled counterparts in precision aiming tasks in sport such as billiards (Williams, Singer, & Frehlich, 2002) and golf putting (Mann et al., 2011). In shotgun shooting, Causer et al. (2010) reported that elite shooters demonstrated a longer relative QE duration than sub-elite shooters, whilst also exhibiting an earlier onset of the QE. A longer QED was also associated with better performance with QED being longer during successful than unsuccessful shots. A potential reason for more successful performance may be due to the longer QED being associated with a more efficient movement patterns. During the all three shotgun disciplines, successful performance was associated with more stable gun motion. A longer QE therefore may allow for a critical time period of self-organisation, allowing a more efficient movement pattern to be planned (Causer et al., 2010). Additionally, the QE has also been shown to differentiate expertise in other fields away from sport. In medicine, a longer QE has been shown by expert surgeons over novices when performing the crucial skill of knot-tying (Vickers et al., 2015). This longer QED was again associated with a higher rated performance and faster movement times. In law enforcement, expert police firearms officers were found to exhibit a longer QED to an assailant's weapon before firing than novices (Vickers & Lewinski, 2011). A longer QE was associated with a more accurate shot, with experts performing significantly better than novices. In addition, during near and far aiming tasks in billiards, an increase in task complexity was found to be associated with a longer QE (Williams, Singer, et al., 2002). The authors again suggested that this longer QED was likely due to a critical period of an individual programming the correct movement parameters for successful performance. However, currently little research exists investigating the effect of task complexity on the QE.

The results of the aforementioned studies consistently report the QE as a factor that is associated with expert performance in various domains involving aiming tasks. Vickers (2016) reviewed the progress in QE research since its conception and aimed to address the current issue facing this research topic. Based on this review, a collective of researchers prominent in the area of QE and perceptual-cognitive skill offered their own standpoints on the future directions of QE research. A key area identified for further investigation was the mechanisms underpinning the QE and the need to understand in more detail the ways in which the QE exerts its beneficial effects. Potentially using a more neuroscientific approach in order to identify the neural structures underlying the QE was suggested by Wilson, Wood, and Vine (2016) and Causer (2016b), whilst Mann, Wright, and Janelle (2016) suggest that more innovative and creative research designs may enable the mechanisms of the QE to be better understood. The replication of previous results was identified by Baker and Wattie (2016) as another important focus for future QE research, as the authors suggest that although meta-analyses and reviews seem to show the QE as a robust phenomenon, there have been discrepancies between results reported from one lab to another in similar tasks. By replicating results, the benefits of the QE that research has alluded to could be more validly relied upon to inform potential training methods. These training methods are currently based around previous findings that when under competitive pressures or increased anxiety, visual search and perceptual-cognitive skills may be negatively affected.

Anxiety and Visual Search

During competition, athletes must perform to the best of their ability under various internal and external sources of pressure; this results in an increased amount of anxiety experienced. The concept of 'choking' under pressure (Baumeister, 1984) has been investigated in a variety of sporting situations such as soccer penalties (Jordet, 2009), cricket matches (Lemmer, 2015) and basketball free-throws (Gómez, Lorenzo, Jiménez, Navarro, & Sampaio, 2015), however, only relatively recently have the effects of anxiety on perceptual-cognitive skills been investigated. In simulated auto-racing, Janelle, Singer, and Williams (1999) investigated the effects of increased anxiety on the visual search strategies of drivers. Through the use of a peripheral light identification task whilst driving, it was found that when experiencing higher amounts of anxiety, participants were slower to identify the lights whilst also suffering a decrement in the primary task of driving. This was shown to be in association with a more eccentric visual search in the distraction anxiety group, suggesting that when anxious, drivers attend to more irrelevant stimuli than when in low anxiety conditions. Similarly, Williams and Elliott (1999) examined the effects of anxiety on visual search and performance during filmed offensive karate sequences. As with Janelle et al. (1999), the authors found that under high-anxiety conditions, participants exhibited an increase in number of fixations and fixation location. The authors suggested that this may be due to peripheral narrowing, which results in increased search activity to compensate for the reduction in usage of peripheral vision. Further, it was suggested that participants may have been more susceptible to task-irrelevant stimuli and therefore distracted more easily during the high anxiety conditions. Additionally, Nieuwenhuys, Pijpers, Oudejans, and Bakker (2008) again demonstrated that during high anxiety conditions, novice climbers increased their number of fixations and also their fixation duration resulting in longer climbing times. It was reported that climbers spent longer fixating task–relevant stimuli such as hand holds, suggesting that the increase in climbing time was due to climbers taking longer to extract relevant information from their fixations. An increase in the number of fixations during performance may also lead to key visual behaviours not being maintained or even excluded from the visual search altogether.

Anxiety and the QE

With visual search being negatively affected by increased anxiety, the ability to maintain a steady final fixation before movement onset may become more difficult. Therefore, recent researchers have attempted to investigate the effect of increased anxiety on the QE (for a comprehensive review see Wilson, Causer, and Vickers (2015)). During a simulated archery task, Behan and Wilson (2008) investigated whether the QE was affected by increased anxiety via a series of ego-stressors. As with previous QE studies, more accurate performance was associated with a longer QE; however, when anxiety was increased, QED was found to decrease. Although the study provides insight into the effects of anxiety of the QE, the main limitation of the study was the use of a simulation and a lack of similar perception-action coupling to a real-life archery task, meaning it does not provide a representative task design (Pinder, Davids, Renshaw, & Araújo, 2011).

As a result, future studies aimed to address this problem by testing the effects of anxiety using a more representative task and environment. In basketball, Wilson et al. (2009) found that for free-throws during a high anxiety condition, QED significantly decreased as did free-throw success rate, compared to during a low anxiety condition. All free-throws were taken to a standard basketball hoop and backboard but were performed in a laboratory condition. Therefore, although the study had a more representative design compared to Behan and Wilson (2008), it was still not testing the effects of anxiety on the QE in a real-world scenario. Causer, Holmes, Smith, and Williams (2011) addressed this issue by examining elite shogun shooters QEDs and performance whilst performing a double target shooting task on a skeet range. It was reported that performance decreased and QEDs shortened during high anxiety conditions compared to low anxiety. The authors suggested that a reduction in QED duration under heightened anxiety can lead to performance decrements due to an inhibition of attentional control.

In contradiction to these findings, Vickers and Williams (2007) examined the effects on performance of both low and high pressure conditions following exercise at different exercise intensities in elite biathlon athletes. It was reported that when exercising at 100% of their individual power output under high pressure conditions, athletes were able to insulate themselves from choking by increasing their QE duration. The authors suggest that this may be due to the individuals focusing their attentional externally to information that is critical for task completion, thereby decreasing the focus on factors such as negative thoughts or pain associated with increased pressure and physical exertion.

However, more recently, to investigate the effect of anxiety on the QE and performance, Vine et al. (2013) split the QE fixation into three components; QE-pre, QE-online and QE-dwell. During a golf putting 'shootout' task, the authors measured total QED and each component's duration for holed and missed putts. It was reported that total QED was shorter on missed putts with the components of the QE occurring during the movement (QE-online) and after ball contact (QE-dwell) being significantly shorter compared to holed putts. The authors suggested that the reduction in QE-online and QE-dwell, and thus total QED, was due to a disruption of attentional control caused by the increased pressure of the shootout task. As with the previous studies to show the negative effect of anxiety on QED, the authors proposed that resources were allocated away from goal-directed processes and towards irrelevant stimuli; explanations based on theories of attentional control.

Processing Efficiency Theory

In an attempt to explain the mechanisms underpinning the effect of anxiety on performance, Eysenck and Calvo (1992) devised the Processing Efficiency Theory (PET). PET is based around two main predictions:

1. *Anxiety typically impairs processing efficiency more than performance effectiveness*

2. *Adverse effects of anxiety on task performance generally become stronger as task demands on working memory capacity increase*

The theory suggests that anxiety causes worry and this worry effects performance in two main ways. Firstly, worrisome thoughts can cause a reduction in the processing capacity of the working memory meaning there are less available resources for concurrent task performance; and secondly, an increase in anxiety can cause a rise in on-task effort and strategies designed to improve performance. A key concept of PET is that it defines a clear distinction between performance effectiveness, the quality of performance, and processing efficiency, performance effectiveness divided by the resources invested in the task (Eysenck & Calvo, 1992). The theory predicts that anxiety impairs processing efficiency more so than performance effectiveness due to the reduction of attentional resources caused by the increased anxiety, being partially or fully compensated by an increase in effort (Williams, Vickers, & Rodrigues, 2002).

PET does not theoretically consider the effects of disruptive stimuli on individuals who are anxious nor the instances whereby anxious individuals out perform their non-anxious counterparts (Eysenck, Derakshan, Santos, & Calvo, 2007). Although many studies have aimed to test the predictions of PET in sports such as golf (Wilson, Smith, & Holmes, 2007), auto racing (Murray & Janelle, 2003), table tennis (Williams, Vickers, et al., 2002), volleyball (N. C. Smith, Bellamy, Collins, & Newell, 2001) and hockey (Wilson et al., 2007); the theory has also been criticised for its imprecision surrounding the effects of anxiety on the central executive and the specifics as to which central executive functions it adversely affects.

Working memory was defined as a functional system by Baddeley (1986), that serves to temporarily store and utilise newly presented information whilst also operating as a temporary workspace for integrating this new information with information stored in the long-term memory. These processes allow tasks such as decision-making, problem solving and preparation of action to take place swiftly. Baddeley (1986) proposed that working memory was comprised of three sub-systems: two short-term storage systems, the phonological loop and the visuospatial sketchpad, and one system that coordinates the information within working memory, the central executive. The central executive serves multiple functions including selective attention and inhibition of non-relevant stimuli, shifting attention between stimuli or tasks and updating working memory (E. E. Smith & Jonides, 1999). Therefore, when under pressure or anxious, it is generally assumed that worrisome thoughts or anxiety exert their effects mainly on the central executive.

Attentional Control Theory

As a result of the limitations of PET, Eysenck et al. (2007) devised the Attentional Control Theory (ACT) with the aim of addressing the issues previously discussed. It does so with the creation of six hypotheses:

1. *Anxiety impairs processing efficiency to a greater extent than performance effectiveness on tasks involving the central executive*
2. *Adverse effects of anxiety on performance become greater as overall task demands on the central executive increase*
3. *Anxiety impairs attentional control by increasing the influence of the stimulus-driven attentional system*
4. *Anxiety impairs efficiency (and often effectiveness) on tasks involving the inhibition function, especially with threat-related distractors*

5. *Anxiety impairs efficiency (and often effectiveness) on tasks involving the shifting function*
6. *Anxiety impairs processing efficiency (and sometimes performance effectiveness) on tasks involving the updating function only under stressful conditions*

In keeping with PET, central to ACT is a clear distinction between performance effectiveness and processing efficiency whilst building upon PET with the assumption that the effects of anxiety on attentional processes are key to understanding how performance is affected by increased anxiety. Anxiety is experienced when a current goal is threatened, causing attentional resources to be allocated towards detecting the source of the threat and deciding how best to respond (Power & Dalgleish, 1997). Attentional focus in the concurrent task is therefore diverted away from task-relevant stimuli and towards more task-irrelevant stimuli. ACT builds upon the work of Corbetta and Shulman (2002) by suggesting that an increase in anxiety experienced disrupts the balance of two attentional systems: the goal-directed system (top-down control) and the stimulus-driven system (bottom up control). As anxiety is increased, the influence of the stimulus-driven system increases and therefore the influence of the goal-directed system decreases. This results in reduced attentional control and the impairment of the shifting and inhibition functions of the central executive. However, these decrements do not necessarily lead to decreases in performance effectiveness, provided that the individual is able to implement additional processing resources and strategies (Vine & Wilson, 2010). By directly addressing the specific functions of the central executive that are affected by anxiety, ACT builds upon PET and overcomes its limitations (Wilson, 2008).

ACT therefore is a leading theory in the distraction focus school of thought, whereby it is suggested that anxious individuals may not have enough attention available to plan and perform movements in relation to the task-specific information available. This distraction model has been used to explain the results of various studies whereby task performance has decreased as a result of increases in task-irrelevant fixations and a reduction in task-relevant fixations (Behan & Wilson, 2008; Causer, Holmes, Smith, et al., 2011; Nieuwenhuys, Vos, Pijpstra, & Bakker, 2011). On the other hand, execution focus models argue that rather than causing a reduction in task-relevant attention, anxiety causes an individual's attention to be focused more internally, which leads to attempts to explicitly monitor and control performance movements (Masters, 1992). Again, various studies have found that by asking participants to focus explicitly on their movement execution, performance was shown to decrease (Gray, 2004; Lam, Maxwell, & Masters, 2009). However, both the distraction and execution focus models are limited as they are restricted to effects of anxiety on attention, and primarily focus on how movement execution is affected by a change in attention. Anxiety has also been shown to affect the way in which information is interpreted, therefore a model that accounts for both the effects of anxiety on attention and how an individual interprets information could provide a more in-depth insight into the mechanisms by which anxiety affects goal-directed action.

Integrated Model

To address the limitations of both distraction focus models, such as ACT (Eysenck et al., 2007), and execution focus models, Nieuwenhuys and Oudejans (2012) developed an integrated model of anxiety and perceptual-motor performance. The authors agree that, in line with ACT, anxiety negatively affects performance due to increased resources being allocated towards bottom-up (stimulus driven) processing and away from top-down (goal-directed processing). However, they suggest that this imbalance not only affects attentional control in terms of a bias towards attending to threat-related information, but also affects interpretational processes and results in emotion-specific behavioural responses (Nieuwenhuys & Oudejans, 2012). As Figure 1.2 shows, the way in which anxiety exerts its effect is split into three distinct operational levels: threat-related attention, threat-related interpretation and threat-related response tendencies. Each of these levels in turn can affect the whole perception-selection-action cycle or individual components of the cycle. In addition, Nieuwenhuys and Oudejans (2012) agree with the suggestion of ACT that anxiety can serve as a motivational function, effecting the efficiency of the performance but not necessarily the effectiveness. The integrated model furthers this principle by suggesting three main ways in which an individual may channel their mental effort: enforcing goal-directed behaviour, actively inhibiting stimulus-driven responses and attempting to reduce feelings of anxiety. Finally, the model suggests that the way in which anxiety is experienced and therefore combatted against depends on both situational (e.g. task constraints) and dispositional (e.g. state anxiety) factors. For a full review of the model and its concepts see Nieuwenhuys and Oudejans (2012). Although the integrated model attempts to further explain the possible mechanisms by which anxiety affects performance, more research is needed to apply the principles suggested by the model. Current research is still largely focused around the main themes of ACT and therefore the in-depth differences in interpretation of anxiety are yet to be fully explored.

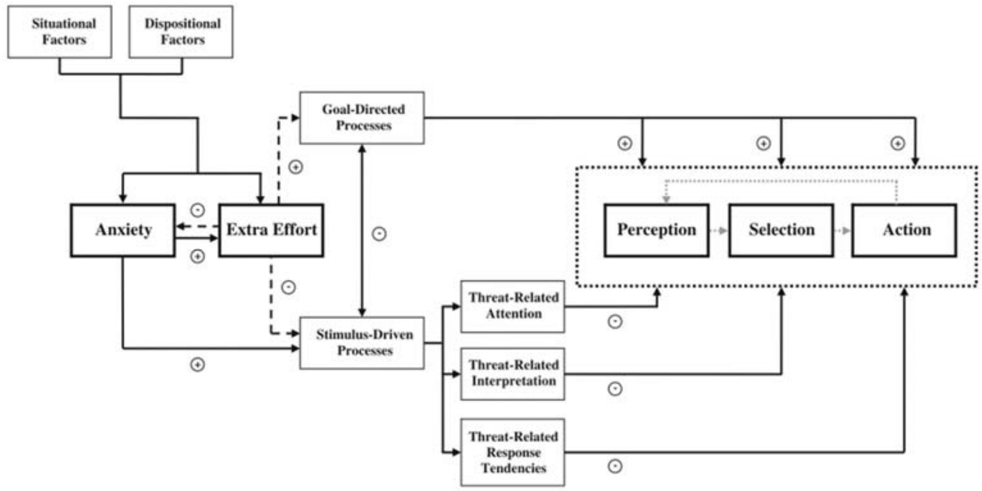

Figure 1.2. Integrated model of anxiety and perceptual-motor performance, adapted from Niewenhuys and Oudejans (2012)

Cognitive Load Theory

PET, ACT and the integrated model are all based around a general concept that working memory has a finite number of resources available for processing and further supporting this assumption is Cognitive Load Theory (CLT) (Sweller, 1994). CLT works from the supposition that each task an individual undertakes is associated with its own cognitive load, meaning that the amount of working memory's limited resources used, depends on the cognitive load that the task creates. This cognitive load can be created from three sources: firstly, intrinsic load concerns how hard the task is to complete and the prior knowledge of the task the learner already possesses; secondly, extraneous load refers to how information is presented to the individual; and lastly, germane loads concerns the amount of resources allocated to developing long-term knowledge or schema of the task being executed. Total cognitive load therefore is calculated through the addition of the three sources. CLT suggests, in line with predictions of PET (Eysenck & Calvo, 1992) and ACT (Eysenck et al., 2007), that if total cognitive load becomes overbearing, task performance may suffer negatively as a consequence (Paas, Renkl, & Sweller, 2003). Whereas PET and ACT focus on how anxiety during various tasks may increase the demand of working memory resources; CLT by also taking into account extraneous and germane load, helps to further understand the reasons for potential performance differences during a task. For example, Runswick, Roca, Williams, Bezodis, and North (2018) found that when performing a cricket batting task under high anxiety, performance decreased with the number of good bat-ball contacts reducing. However, when manipulating situation-specific contextual information, performance was also negatively affected but with the number of complete misses of the ball increasing significantly. The authors report that this is due to increases in anxiety affecting individuals at an attentional level, as shown by increased fixations under high anxiety, whereas during high situation-specific context conditions, behaviour was also affected. This suggests that anxiety and performance are potentially affected through different mechanisms. Thus, through further understanding the different factors that may affect cognitive processing and thus performance, it has been possible to investigate the development of methods by which individuals can train in order to negate some of the negative effects of anxiety and increased attentional load.

Perceptual-Cognitive Skills Training

Researchers have recently identified that the perceptual-cognitive skills that underpin expert performance in sport can be trained (Savelsbergh, van Gastel, & van Kampen, 2010). These perceptual-cognitive skills training programmes have been suggested to improve the acquisition of expert performance by increasing the knowledge base of the individual (Broadbent, Causer, Williams, & Ford, 2015; Causer, Janelle, Vickers, & Williams, 2012; Williams & Ward, 2003). Following the expert performance approach, early research focused on the possibilities of improving individual's anticipation and decision making through the use of video-based representative tasks. By using such methods, researchers are able to expose individuals to key scenarios that they would experience in competition, but in a more repetitive manner than normal. For example, Singer et al. (1994) examined the effect of anticipation training on individuals ability to earlier identify shot direction correctly. A 'mental quickness' group trained by simply watching videos of various tennis shots whilst receiving verbal tips about visually identifying relevant cues that may help with anticipating the type and direction of the shots. Whereas a 'physical quickness' group watched the same videos, were not given the verbal instructions and had to perform the relevant physical response to the shot they predicted. After a three-week programme, the mental quickness group were shown to be better able to make faster decision in reaction to serves, predict shot type and location better, and showed faster anticipation time than in their pre-test. The physical quickness group on the other hand showed no improvement. These results suggested that perceptual-cognitive skills in lesser-skilled individuals could be trained in an attempt to expedite acquisition of expertise. They also showed that representative tasks whereby individuals were directed towards task-relevant information can enhance performance in a laboratory setting. However, Singer et al. (1994) omit the physical movement component of performance for the mental quickness group and therefore the study is limited in its application to improving performance for real-life competition. Although individuals may anticipate the type of shot earlier, they may not be able to physically move quickly enough to make that advantage count, therefore performance outcome could likely be the same as if they did not anticipate the correct shot (Drugowitsch, Moreno-Bote, Churchland, Shadlen, & Pouget, 2012).

One such way of addressing this limitation is incorporating a perception-action paradigm into the experimental design. Action fidelity, the performer completing a response that mirrors that of a competitive situation, was identified by Pinder et al. (2011) as one of two key components in experimental research design. The second, task functionality, refers to the how well the task contained within the experimental design matches that of a real-life competitive scenario. Research into the training of perceptual-cognitive skills should therefore involve, as much as is possible whilst still allowing for experimental control, participants to process and execute perceptual-cognitive skills in the same manner they would during a competitive event in their sport (Broadbent, Causer, Williams, et al., 2015). One such example of research that allows for action fidelity and task functionality was conducted by Dicks, Button, and Davids (2010). Through the use of an occlusion paradigm, soccer goalkeepers were tasked with saving penalty kicks having had varying amounts of visual information from the kickers run up under both deceptive and non-deceptive conditions. The authors classified the goalkeepers' responses on a five point rating scale depending on the level of success they had in saving the penalty. It was found that goalkeepers performed better under non-deceptive conditions and the authors concluded that there was no benefit to having access to the kinematic information of the run up compared to that of simply the later information prior to kicking of the ball. Farrow and Abernethy (2003) also aimed to investigate the degree to which perception-action coupling affected anticipation in tennis by having individuals perform under one of two conditions: coupled, in which participants were required to make a movement-based response to a serve as they would in a match situation; and uncoupled, whereby participants gave a verbal prediction of ball flight. Two experiments, the first involving expert and novices whilst the second involved intermediate skilled players, revealed that the perceptual processes used in anticipation differs between skill levels, what kind of information is presented and most importantly the degree of perception-action coupling required for performance (Farrow & Abernethy, 2003). Further, during their first experiment it was found that participants in the coupled condition were better able to predict ball flight and direction than those in the uncoupled condition. Therefore, it is clear that when attempting to provide conditions for training perceptual-cognitive skills, the level of perception-action coupling should be of the upmost consideration.

Training of perceptual-cognitive skills has been shown to be beneficial in sports such as soccer (Savelsbergh et al., 2010), tennis (Broadbent, Causer, Ford, et al., 2015; Williams, Ward, Smeeton, & Allen, 2004) and badminton (Hagemann, Strauss, & Cañal-Bruland, 2006). Such effects have focused on the ability to pick out key information from an environment which in turn can lead to improved performance. However, with recent research identifying the QE (Vickers, 1996c) as an individual visual search behaviour which may lead to increased performance, the ability to train such a skill has become of paramount interest to researchers interested in improving human performance.

QE Training

An early attempt to investigate the possibilities of training the QE was by Adolphe, Vickers, and LaPlante (1997) who reported that after a six week visual attention training programme for volleyball serve receiving, individuals exhibited an improved ball detection onset, duration and offset. Further, this was coupled with improvements in step corrections. In a three year follow up, those who had been visually trained had significantly higher accuracy in passing to their teammates following the serve than those who had not, despite the fact no specific technical instruction had been given during the training. Similarly, Harle and Vickers (2001) using a two-season training programme, found that after the first season, a QE trained basketball team significantly improved their free throw shooting in the experimental conditions compared to two control teams; but did not transfer these improvements to a competitive environment. However, after the completion of the second season of training, the QE trained team had a significantly improved their free throw shooting accuracy in competition from 22.62% to 76.66%; more than both control groups. These results suggested that not only can QET help to improve performance of a basketball free-throw compared to no perceptual-cognitive skills training, but these improvements can transfer to a competitive environment. Further, the results showed that QET may not produce immediate results but may exert its effect on performance accuracy with continuous training over an extended period of time.

In addition to the effects on performance outcome, QE training and thus a longer QE has also been found to benefit both performance kinematics and physiological factors. Over a seven day period, Moore, Vine, Cooke, Ring, and Wilson (2012) administered either a QE training or a technical training (TT) programme to novice golfers. After training and in a pressure transfer test, the authors reported that not only did the QE trained group perform more accurately and exhibit more effective visual control than the TT group, they also showed lower clubhead acceleration, a greater heart rate deceleration and more reduced muscular activation. These results suggested that QE training could lead to a movement pattern that is more expert-like even when there are no specific instructions given that relate to the movement of an action. Further, a deceleration in heart rate and reduced muscle activation suggest that QE training may enable the maintenance of an external focus of attention during performance under pressure.

Following on from early investigations into QET (Adolphe et al., 1997; Harle & Vickers, 2001; Oudejans, Koedijker, Bleijendaal, & Bakker, 2005), various studies have attempted to investigate the ability of QET to combat the negative effects of increased anxiety. One of the first studies to do so was Vine and Wilson (2010) who examined the effects of an eight day QET programme in golf putting. It was found that those who had been given QET maintained significantly better attentional control, exhibited by a longer QED, and also performed significantly better in a pressure test compared to a control group. Further to this, a longer QE was associated with better performance across all test putts. These results reflect those of Moore et al. (2012) who reported that more accurate performance and more effective visual control was shown by participants who had been QE trained, over those who had not during retention and pressure tests. Further, this maintenance of performance under pressure was associated with more efficient clubhead kinematics, greater heart rate deceleration and reduced muscle activity potentially showing the role of the QE in the self-organisation of the putting movement, considering no specific coaching or technical instructions were given. Similar performance benefits under pressure have been replicated in a number of studies across a number of domains such as basketball free-throw shooting (Vine & Wilson, 2011), shotgun shooting (Causer, Holmes, & Williams, 2011), surgery (Causer, Harvey, Snelgrove, Arsenault, & Vickers, 2014) and soccer (Wood & Wilson, 2011; Wood & Wilson, 2012).

QET's ability to protect individuals somewhat from the negative effects of anxiety has been attributed to a number of possible mechanisms. As discussed earlier in the chapter there are arguments for a pre-programming mechanism of the QE (Vickers, 1996c) and a more online-control mechanism of the QE (Vine et al., 2015). QET could therefore work by extending the period for an individual to programme the correct movement pattern thus helping to maintain performance under pressure. However, QET could also help by extending the length of the fixation that occurs during movement, leading to a more accurate performance execution and thus performance under pressure could be maintained (Vine, Moore, & Wilson, 2014). Further to these mechanisms, QET may also provide the individual with an external focus of attention during action execution. Wulf, Shea, and Lewthwaite (2010) suggest that an internal focus of attention on one's own movements results in a type of control that is more conscious and therefore uses up more resources of the motor system. In contrast, adopting an external focus of attention (e.g. dimples of a golf ball), promotes the utilisation of more automatic or unconscious processes which may result in better performance. As such, QET may give individuals an exact external focus of attention allowing them to focus solely on performance outcome (Vine et al., 2014). This means that although they may experience some of the negative

Table 1.1. Summary of previous Quiet Eye research in golf putting

TITLE	AUTHORS	JOURNAL	PARTICIPANTS	EQUIPMENT	PROCEDURE	INDEPENDENT VARIABLES	DEPENDENT VARIABLES	KEY RESULTS	CONCLUSIONS
On the interaction of attentional focus and gaze: The quiet eye inhibits focus-related performance decrements	Klostermann, A. Kredel, R. Hossner, E. J.	Journal of Sport and Exercise Psychology, 2014, 36, 392-400	12 Expert Golfers (8 men, 4 women) Mean handicap = 6 12 Near-Expert Golfers (7 men, 5 women) Mean handicap - 25.6	Standard Indoor Green Carpet 2.5x10m Putting accuracy and movement phases measured using VICON system, reflective markers on putter, ball and head EyeSeeCam 220Hz to track participants gaze	Putting a golf ball on a flat surface to stop on a target cross 3m (9ft 9in) away 16 warm up trials, calibration of eye tracker, 16 Test trials in each focus of attention condition Instructions given after every 4 trials	Movement related instruction Effect-related instruction Expertise	Putting Performance (how far from the target cross) Quiet eye Head Movement Initiation	Experts had a better putting performance (M=244.1mm radial error) than near experts (315.4mm) Performance was better for the effect-related instruction Experts had a longer quiet eye duration (M = 2235.0 ms) and an overall later QE offset (M= 1177.9 ms) than near experts The longer QE was linked to better performance	Performance is improved with an effect-related instruction rather than a movement-related Experts produce longer QE durations and this is linked with better performance outcomes QE offset matters more in a online demanding task than QE onset
Quiet eye training facilitates competitive putting performance in elite golfers	Vine, S.J Moore, L.J Wilson, M.R	Frontiers in Psychology, 2011	22 elite male golfers Mean handicap = 2.78 All right handed	Artificial putting green Length 6m x Width 2.5m All golfers used their own putters and standard white golf balls ASL Mobile Eye Tracker in conjunction with Eyevision software Quiet eye solutions	Participants recorded their competitive putting performance for 10 rounds (pre training measure) Randomly assigned to QE or control group 10 practice putts then 20 pre-test putts (2 blocks of 10) 20 putts then taken during training regime Straight putts taken from 3, 10ft locations to a standard size hole (10.80cm diameter) Given more scorecards to record 10 rounds of competition putting Retention 20 putts and 15 pressure putts	Training group Anxiety	Performance Outcome (putts holed) Performance Error (distance from hole) Number of putts per round and number of putts from 6-10ft Quiet eye	Anxiety was significantly higher in the pressure test QE trained group had significantly longer QE (m = 2794.31ms vs m = 1404.74ms) and holed significantly more putts during pressure test (m= 60% vs m= 36%) QE performed sig better than control in retention(mean error = 4.58mm vs 8.37mm) and pressure tests (me = 4.45mm vs 10.28mm) QE trained had sig fewer putts per round than control post training (mean = 27.61 vs 29.89) and from pre to post training , also holed more 6-10ft putts	QE length increased through the intervention of QE training Shorter QE during pressure for control led to poorer performance, QE trained protected them In effect, by holding a ball focused QE throughout the putting stroke and through impact, golfers are able to ensure a more accurate contact with the sweet spot of the putter, ensuring more consistent ball strike
Visuomotor control of straight and breaking golf putts	Wilson, M.R Pearcy, R.C	Perceptual and Motor Skills, 2009, 109, 555-562	6 University Team golfers (no handicap given) All right handed	Artificial putting green Length 4.9m x Width 1.2m Green was able to be angled using wooden struts Titleist Pro V1 Balls and own putter ASL Mobile Eye Tracker	25 3m putts 5 in each condition (flat, 0.9º R to L, L to R, 1.8º R to L, L to R)	Putting Condition	Performance Outcome (holed or missed) Performance error (distance from the hole) Number of aiming fixations Duration of final aiming fixation Quiet eye	Performance error was significantly higher in the severe slope condition over the moderate slope or flat condition (16.13cm vs 7.20cm vs 5.17cm) Significantly shorter QE period on missed putts (1231.03ms vs 1693.50ms) Significantly more fixations on sloped putts (7.94 vs 5.93)	Even a consistent side slope of between 0.9° and 1.8° increased the difficulty of the putting task and created more parameters to be processed by the visuomotor system Visual processing measures be assessed dur-ing the preparation and execution of sloped (as well as flat) putts to fur-ther understanding of the mechanisms underlying successful putting performance A sufficiently long quiet eye period is the decisive visuomotor measure for ensuring a successful putt and that aiming fixations are not as critical
Gaze control in putting	Vickers, J.	Perception, 1992, 21, 117-132	5 Low Handicap Golfers (mean = 6.2, range = 0-8) 7 Higher Handicap Golfers (mean = 14.1, range = 10-16)	ASL 3001H Mobile eye view monitor Astro turf putting surface Length 8.83m x Width1.82m Aiming at a plastic cup Own putter but same high quality balls	20 Practice trials for familiarisation Putt in sets of twelve until ten hits and ten misses recorded	Expertise (handicap level) Putting distance (3m)	Gaze Frequency and duration Gaze during different phases of movement	LH had longer fixations on the ball and target LH had fewer fixations on the club and surface than HH	A successful putt was more likely if the golfer kept a steady fixation on the ball during back/foreswing as well as on the surface during contact

Quiet eye training expedites motor learning and aids performance under heightened anxiety: The roles of response programming and external attention	Moore, L. J. Vine, S. J. Cooke, A. Ring, C. Wilson, M. R	Psychophysiology, 2012, 49, 7, 1005-1015	40 novice undergraduate students with no golf putting experience	ASL Mobile eye tracker Artificial putting green Length 6m x Width 2.5m Ping Sedona 2 Putter and standard white golf balls	Putts from 3 different 10ft locations Participants randomly assigned to technical or QE trained group 40 Pretest putts Day 1 Training 2 x 40 putts Days 2+3 3x40 putts Day 4 20 putts for retention test Day 5 20 x competition putts in pressure test, followed by 20 putts as second retention test	10ft (3.05m) Putting distance Training Group	Cognitive Anxiety Perfromance (putts holed and mean radial error) QE duration Cardiac activity Putter Kinematics Muscle Activity	Anxiety increased for both groups in pressure test QE trained holed a higher percentage of putts than TT QE had lower mean radial error in retention and pressure tests TT showed higher MRE in pressure test over retention QE had longer QE durations during retention and pressure tests and durations were not sig different between the two tests TT had shorter QE duration in pressure test than they did in retention QE trained had better putter kinematics than TT, y-axis acceleration can be considered a partial mediator between groups for MRE in retention tests QE holed 7.5% more putts and were 10cm closer on missed putts QE revealed a phasic heart rate change patternacross retention and pressure tests that is congruent with the pattern exhibited by elite and experienced golfers	The results suggest that the quiet eye training intervention acted to protect performers from the adverse effects of heightened anxiety upon performance By training one group to adopt the gaze control strategies of experts, they were able to “cheat experience” and move further along the learning curve than their technical trained counterparts These results are congruent with previ-ous research and dem-onstrate that the quiet eye training intervention indirectly crafted a change in putter kinematics, making putter movement more expert-like, despite training instructions being related to gaze control only The phasic heart rate change reflects a greater external focus of attention towards task relevant cues compared to the tech-nical trained group
How can novel task constraints be used to induce acute changes in gaze behaviour?	Panchuk, D. Farrow, D. Meyer, T.	Journal of Sports Sciences, 2014, 32,12, 1196–1201	29 amateur golfers (Handicap range 1-41)	Coloured markers Putting box of science (PBoS) ASL Mobile Eye Indoor putting surface Own putter	Randomly assigned to control, hole focus, marker and PBoS groups 10 straight 6ft (1.83m) putts for pretest 15 condition putts from 4ft (1.22m) and 8ft (2.44m) on outdoor putting green 10 6ft (1.83m) putts for post-test	Putting distance Group	QE duration QE dwell duration Putting accuracy (number of putts holed)	No significant differences in putting accuracy between groups in pre and post-test No change in QE for control or PBoS groups, decline for hole focused and increase for marker QE was significantly longer on hits than misses QE dwell time increased only for the marker group QE dwell duration increased for hits post-test but did not change for misses	Comparisons of three different training interventions demonstrated that QE could be manipulated through training aids in a variety of directions (increased or decreased duration) and specific aspects of gaze behaviour (QE dwell time) could be targeted as well Able to change gaze behaviour with-out providing direct instruction to golfers. Implicit learning techniques allow performers to acquire skills without engaging their working memory and preventing the accrual of declarative knowledge
Champ or chump? Challenge and threat states during pressurized competition	Moore, L. J. Wilson, M. R. Vine, S. J. Coussens, A. H. Freeman, P.	Journal of Sport and Exercise Psychology, 2013, 35, 6, 551-562	60 Golfers (4 women, 56 men) Mean handicap = 10.02	ASL Mobile Eye Tracker Cardiograph device Immediate anxiety measurement scale Concious motor programming subscale Tri-axial accelerometer (LIS3L06AL, ST Microelectronics, Geneva, Switzerland) and bespoke buffer amplifier (with a frequency response of DC to 15 Hz) EMG electrodes	Split into two groups, challenge and threat Six straight putts from three, 2.44 m locations to a half-size hole (diameter = 5.4 cm) on an artificial putting green (length = 6 m, width = 2.5 m; Stimpmeter reading = 3.28 m).	Group Putting Location	Cognitive and somatic anxiety Concious processing Percentage of putts holed Performance error QE duration Cardiovascular measures Putter kinematics	Challenge group had : significantly longer QE duration less concious processing signifcantly lower somatic and cognitive anxiety more putts holed and lower performance error significantly larger challenge and threat index value	The challenge group exhibited a cardiovascular response consisting of relatively higher cardiac output and lower total peripheral resistance compared to the threat group Results congruent with previous research demonstrating that a challenge state typically facilitates performance whilst a threat state generally hinders performance

effects of anxiety, they may not experience them to the same degree as those who have not been QE trained. However, further research is needed to investigate further the mechanisms by which QE training exerts its beneficial effects on performance under pressure.

Anxiety and Attention Training

QE training has been shown to help negate the negative effects of anxiety upon performance, but training under heightened anxiety could also be a method by which individuals acquire the skills to performance consistently in an high pressure environment (Nieuwenhuys et al., 2011). Following an anticipation training programme in badminton, Alder, Ford, Causer, and Williams (2016) found that individuals who had been trained under high anxiety conditions demonstrated higher response accuracy when responding to video representations of shots in a high anxiety post-test, than those who had been trained under low anxiety or control conditions. Further, in the low anxiety post-test, both training groups demonstrated greater response accuracy and final fixation duration than at pretest and also than the control group. Likewise, through a 5-week training programme, Oudejans and Pijpers (2009) examined whether training under high and low anxiety conditions affected performance in a high-pressure post-test. Results showed that participants trained under high anxiety conditions performed better in the anxiety post-test than those trained under low anxiety conditions. Acclimatisation to the heightened anxiety was suggested to be the significant factor in the performance differences in the two groups. The authors suggest that acclimatisation may be a quick process whereby an individual may recalibrate existing motor skills to new constraints, thus fewer resources are needed for the primary task when put into a high pressure situation. This then allows more resources to be invested in strategies to counter act the negative effects of anxiety (Eysenck et al., 2007). During the anxiety test in Oudejans and Pijpers (2009), the threat of physical sanctions for both individuals and whole team were used to invoke a high-pressure response. However, the threat of physical exertion is just one method of increasing anxiety within a population.

ACT (Eysenck et al., 2007) suggests that there is a fundamental link between anxiety and attention. By increasing attentional load, as with increasing anxiety, an impairment of the inhibition and shifting functions of the central executive should be observed. Thus, performing a secondary task concurrently with the primary task would result in an increase in demand for the use of the same attentional resources, therefore the full capacity of working memory might be needed to maintain performance (Kahneman, 1973). Nibbeling, Oudejans, and Daanen (2012) examined the effect of single and dual-task conditions in both low and high anxiety conditions. Although there was no significant decrease in performance found for the dual-task conditions, response rate during dual-task under heightened anxiety was shown to decrease. This suggests that processing efficiency decreases as mental effort increases and by increasing anxiety levels, metal effort increases further. However, currently high anxiety training along with high attention training have been somewhat overlooked as methods by which to increase sporting performance under pressure. Further to this, the link between QET coupled with high anxiety training on performance is yet to be examined altogether.

Aims of the Thesis

The aim of the current thesis is to investigate the mechanisms that underpin perceptual-cognitive skills during expert performance in aiming tasks. Specifically, the thesis will aim to examine how manipulations of task complexity, anxiety and attentional load may affect these skills in expert and novice performers. Comparisons of visual behaviours and various psychometrics under the different task constraints will aid in the subsequent creation of a perceptual-cognitive skills training programme for novices, aimed at improving performance under increased anxiety and attentional load.

At present there is somewhat of a paucity in the literature regarding the effects of task complexity on perceptual-cognitive skills in sport, whilst the link between task-complexity, perceptual-cognitive skills and skill level is yet to be examined together. Therefore, the aim of Chapter 2 is to identify the perceptual-cognitive mechanisms that underpin expert performance in aiming tasks by investigating how the visual search and cognitive processes of expert and near-expert golfers differ during varying complexity of golf short game shots (putts and chips). Currently no research exists investigating the role of the QE during golf chip shots; as such, total QED will be taken as a measure of visual attention for all shots and will also be split into three components; QE-pre, QE-online and QE-dwell. These components aim to provide further insight into the importance of the timing of the QE fixation during action execution. In addition, for both putting and chipping tasks, absolute error from the hole will measure performance outcome, whilst concurrent verbal reports will be used to measure cognitive processes in the preparation, execution and evaluation of shots. Through the measurement of cognitive processes, it may be possible to identify whether performance differences are occurring due to physical performance breakdown, measured by club kinematics, or a breakdown in cognitive processes.

Having identified the key mechanisms that underpin expert performance in aiming tasks, the aim of Chapter 3 is to examine the effects of increased anxiety and attentional load on performance. During both high and low anxiety and high and low attention conditions, the intention of the chapter is to test predictions of ACT (Eysenck et al., 2007) during a basketball free-throw task. Increased anxiety has previously been linked with decreased performance and a shorter QED due to the disruption of processing efficiency and in turn performance effectiveness. However, as of yet an increase in attentional load has not been examined with regards to its effects on perceptual-cognitive skills and performance in aiming tasks. Therefore, identifying whether an increase in attentional load results in similar processing disruptions will enable better training methodologies to aid in performance under pressure to be designed.

The aim of Chapter 4 is to implement a novel approach to training perceptual-cognitive skills for increased performance under pressure during a golf putt for novice golfers. Through the use of QE training under high and low attention conditions, visual attention and performance will be measured and compared against a technical trained control group. A three-visit design will allow pre, post and transfer tests to be assessed for the different training groups with regards to skill acquisition, retention of skill and performance under pressure.

In conclusion, Chapter 5 will aim to synthesise all of the findings from the body of work into a succinct summary of the potential theoretical and applied implications of the thesis. In addition, future directions are discussed in order to provide a clear understanding of how research into attentional control and perceptual-cognitive skills training can be advanced.

Chapter 2:

Skill-based differences in the visual search strategies and cognitive processes during shot preparation and execution in short game golf shots

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Chapter 3:

Examining the effects of increased anxiety and attentional demands on Basketball free throw shooting

Abstract

The Quiet Eye period (QE), the final fixation before critical movement onset, has been found to be negatively affected by an increase in anxiety (Wilson et al., 2009). However, the mechanisms by which anxiety affects the QE are still debated. Attentional Control Theory (ACT) (Eysenck et al., 2007) suggests that under increased anxiety, attentional resources are allocated towards task-irrelevant stimuli and away from goal-directed processes. Therefore, the current chapter aimed to test whether an increase in attentional load exhibits the same negative effects on the perceptual-cognitive skills and performance as an increase in anxiety. 12 skilled and 12 novice basketballers performed 10 standard free-throw shots under four counter balanced conditions: low attention-low anxiety, low attention-high anxiety, high attention-low anxiety and high attention-high anxiety. A novel tone-response dual-task paradigm was used for manipulating attention, whilst visual behaviours, perceived mental effort, anxiety levels and performance were measured. QED was found to be significantly longer during the low attention conditions than the high. With anxiety also being reported as significantly higher during the high attention conditions than the low, predictions of ACT are supported in that under high anxiety attention may have shifted from goal-directed control to more stimulus-driven control. The reductions in QED were not associated with a decrement in performance, however, with mental effort significantly increasing under high attention conditions, it is possible that individuals were able to implement supplementary strategies to negate the negative effects on performance.

Introduction

Attending to task salient cues during competitive performance has been shown to be a differentiating factor of sporting expertise (Roca et al., 2011). Elite individuals not only possess the ability to better focus on relevant stimuli, but can also process this information in a way that is more efficient and thus more effective for performance (Williams, Singer, et al., 2002). However, in any competitive environment, the levels of pressure on an individual and the number of possible distractions from the task are increased. Therefore, a current research trend has been to examine the effect of anxiety on performance and specifically the way in which anxiety effects the perceptual-cognitive skills of individuals (Vickers & Williams, 2007; Wilson et al., 2009).

High-anxiety inducing conditions have been found to inhibit an individual's performance in various tasks such as the basketball free throw (Wilson et al., 2009), shotgun shooting (Causer, Holmes, Smith, et al., 2011) and during table tennis shots (Williams, Vickers, et al., 2002). Performance decrements in these studies have been attributed to mechanisms involved with Eysenck and Calvo (1992)'s PET and the ACT (Eysenck et al., 2007). ACT suggests that as anxiety increases, the amount of resources allocated to identifying and selecting an appropriate response to the threat perceived are also increased. This shift in resources from task-relevant stimuli or the goal-directed attentional system, towards task-irrelevant stimuli or the stimulus-driven attentional system (Corbetta & Shulman, 2002), results in decreased processing efficiency which can ultimately lead to decreased performance effectiveness. However, ACT suggests the negative effect on performance effectiveness depends on whether working memory is functioning at full capacity. If sufficient resources are still available to adequately process goal-related actions, performance will not suffer.

Secondary task performance has also been shown to have negative effects on performance outcome (Nibbeling et al., 2012). If explained solely using predictions of ACT (Eysenck et al., 2007), it could be suggested that this reduction in primary task performance is due to attentional resources being allocated to identifying and nullifying the task-irrelevant stimuli. However, CLT (Sweller, 1994) suggests that working memory resources available for primary task completion depends on the resources used by the cognitive load associated with the task. This cognitive load is created from three main sources; intrinsic load, extraneous load and germane load (Runswick, Roca, Williams, Bezodis, McRobert, et al., 2018). Therefore, CLT predicts that if information is presented that is irrelevant to the primary task, extraneous load would increase due to the information not being processed through existing schemata associated with the primary task. This could then lead to a reduction in primary task performance, due to the limitation of working memory resources available to complete the task. This assumption is similar to ACT's third hypothesis that the negative effects of anxiety on performance will increase as overall task demands on the central executive increase (Eysenck et al., 2007). Runswick, Roca, Williams, Bezodis, McRobert, et al. (2018) found that by increasing cognitive load through introducing more situation-specific contextual information, performance was affected more so than under high anxiety conditions. As previously shown in Chapter 2, task complexity did not have the predicted effects on perceptual-cognitive skills, thus secondary task performance may be a more useful tool for addressing performance and perceptual-cognitive skills under increased cognitive workload.

One perceptual-cognitive behaviour that has been shown to be negatively affected by increased anxiety is the QE. First identified by Vickers (1996a), the QE is defined as the final fixation to a specific location before movement onset. Although in Chapter 2 no association was found between increased QED and performance, it was suggested this was due to the inclusion of increased task complexity for which there has been relatively little research. By increasing task complexity, although QE durations may have increased in order to aid in the performance of the short game shots, this may not have been sufficient enough to stop larger performance errors than when completing simpler tasks. However, there is a large literature base showing that a longer QE is associated with improved performance in sports such as shotgun shooting (Causer et al., 2010), ice-hockey (Panchuk, Vickers, & Hopkins, 2016) and golf (Mann et al., 2011). Recent studies have also shown that anxiety can reduce QED, possibly due to the individual allocating more resources to task-irrelevant stimuli and therefore not holding a steady gaze prior to movement execution (Behan & Wilson, 2008). This reduction in QED may therefore contribute to a sub-optimal performance, characterised by detrimental changes in movement kinematics (Causer, Holmes, Smith, et al., 2011) and inefficient processing of relevant information from the environment (Vine et al., 2013), in scenarios where attentional load is increased. In addition, higher skilled individuals have been found to exhibit longer QED's than their lesser-skilled counterparts in various aiming tasks (Wilson et al., 2015). It is therefore paramount to identify how increased attentional load can affect performance and whether further skill-based differences in QED occur.

With individual perceptual-cognitive skills, such as the QE, having been found to be negatively affected by increased anxiety and thus being associated with decreased performance; the aim of the current chapter was to investigate further the assumptions that these decrements are due to increased attentional load by introducing a dual-task paradigm during a basketball free-throw, coupled with both high and low anxiety conditions. ACT (Eysenck et al., 2007) hypothesises that anxiety impairs processing efficiency on tasks involving the shifting and inhibition functions of the central executive, whilst CLT (Sweller, 1994) suggests that an increase in task-irrelevant information will increase the extraneous load an individual experiences, potentially leading to performance decrements if total cognitive load consumes a large proportion of working memory's limited resources. Therefore, it was predicted that during both high anxiety and high attention conditions both performance and QED would decrease (Wilson et al., 2009), compared to during low anxiety and low attention conditions. Further to this, it was predicted that a longer QE would be associated with better performance (Williams, Singer, et al., 2002) and that skilled participants would both perform better and exhibit longer QED's than novices (Causer et al., 2010).

Method

Participants

12 skilled (Mean Age: 21.92 ± 4.40 years, Mean Number of Years' Experience in Competitive Basketball: 6.75 ± 3.89 years) and 12 novice (Mean Age: 17.75 ± 3.89 years, Mean Number of Years' Experience in Competitive Basketball: 0 ± 0) basketball players were recruited from local basketball teams, university cohorts and local colleges. Skilled participants were individuals who had played a level of basketball above that of high school standard, i.e. local club, national league. Novices were individuals who either had never played basketball before or those who had only played occasionally for high school.

Ethical approval from Liverpool John Moores University was gained before the initiation of testing and all participants attended individually.

Apparatus

Indoor basketball court

All shots were taken from the standard free-throw line distance of 4.6m to a standard height hoop (3.04m). In keeping with the National Basketball Association guidelines, a Spalding (Kentucky, USA) SZ7 ball was used for all trials.

Eye tracking

A Tobii (Tobii AB; Stockholm, Sweden) Pro Glasses 2 eye tracking system was used to capture and record eye movements (100 Hz). All eye movement data and video footage was stored on an SD card in the wireless portable recorder unit which was wearable by the participant. The SD card was then inserted into a Dell Inspiron laptop installed with Tobii Pro Glasses Analyser software allowing post-recording viewing of both the scene camera and point of gaze, represented by a circular cursor.

Measures

Performance

Free-throw performance was measured using a points system: 3 points were awarded if the ball went into the basket without touching anything but net, i.e. ‘swish’, 2 points were awarded if the ball went into the basket having only touched the rim of the basket and nothing else, and 1 point was awarded if the ball came into contact with the backboard at any time during the shot. Zero was awarded for a miss.

Anxiety

Anxiety was measured using the Mental Readiness Form-3 (MRF- 3). The MRF-3 (Krane, 1994) uses three bipolar continuous scales from 1 to 11 (worried-not worried/tense- not tense/confident -not confident) to measure three items (somatic anxiety, cognitive anxiety, self-confidence). Participants are required to circle the number on the scale that corresponds to their feelings at a given time. MRF-3 measures were taken at the half way point and end of each block of 10 throws.

Mental Effort

The Rating Scale for Mental Effort Form (RSME) (Zijlstra, 1993) was used for measuring mental effort. A scale consisting of a vertical axis ranging from 0 to 150, this one-dimensional form uses nine verbal anchors corresponding to a value including 0 (absolutely no effort), 75 (considerable effort), and 115 (extreme effort). Participants are asked to mark a point on the scale that indicates the mental effort invested in for the task performance. RSME measures were taken at the half way point and end of each block of 10 throws.

Quiet Eye

The QE was operationally defined as the final fixation of a minimum 120ms prior to extension of the forearm before ball release (Wilson et al., 2009). QE offset occurred when the gaze deviated from the location by 1° of visual angle for more than 120ms. The QE was not limited to the final fixation to the rim of the basket, as novice basketballers may not necessarily fixate the rim at all during execution of a free-throw.

Dual-task response accuracy

An auditory stimulus is thought to only take 8-10ms to reach the brain, while a visual stimulus takes 20-40ms. As a result, reaction time to sound is 20-60ms quicker than reaction times to visual information (Kosinski, 2010). Therefore, for the current study auditory tones were used as a concurrent dual-task. A random sequence of high (2000 Hz) and low (500 Hz) tones, each separated by 750ms, were made into 15-second-long clips and manually played through an iPod (Apple, USA) connected to external speakers. The participant was instructed to respond to each tone as quickly as possible with the response of either "high" or "low" depending on which tone was heard. Dual-task performance was measured as a percentage accuracy of response to the pre-set tones in each sequence, adapted from previous dual-task measurements (Gabbett & Abernethy, 2012), recorded using the in-built microphone of the Tobii Eye-Tracking system..

Experimental Tasks

Single Task

Each participant was required to take 10 free throws from a standard free-throw line, a distance of 4.6m, to a standard height hoop (3.04m).

Dual-Task

Participants underwent the same protocol as in the single-task condition; with the addition of the auditory reaction time task. The preparation (after catching a pass and before the first upward motion of the ball) and pre-shot (first upward motion the ball before reaching chest level) phases of the basketball free-throw were identified by (Price, Gill, Etnier, & Kornatz, 2009) as the phases requiring the greatest attentional demand. Therefore, in the current experiment, the auditory tones were administered from the start of the trial until the ball had hit the floor post-shot.

Experimental Conditions

Low Anxiety

Participants were asked to do their best and it was outlined that their performance scores would not be recorded and compared against other participants.

High Anxiety

A series of ego stressors were administered to increase anxiety. Participants were informed that all individual scores would be recorded for comparison to all other participants in a competition scenario; they were also informed that for the top three performers, there would be prize money of £100 for first, £50 for second, and £20 for third place. Participants were also filmed by a GoPro (California, USA) Hero 4 Session camera mounted on a tripod and placed in front and to the side of the participant.

Procedure

After providing consent, participants were fitted with the eye tracker. Once calibrated, the participants were each allowed three practice free-throws to familiarise themselves with the environment and wearing the eye tracker whilst performing. After familiarisation, they began their first of the four counterbalanced experimental conditions. For each condition, participants were required to take ten free throws and were instructed to shoot to the best of their ability. Calibration of the eye tracker was done before every block of 10 throws and a new recording initiated. After 5 trials and at the end of each condition, the MRF-3 form and RSME form were completed by the participants.

Data Analysis

A series of 2 Group (Skilled, Novices) x 2 Anxiety (High, Low) x 2 Attention (High, Low) mixed design ANOVAs were run to analyse performance, QE, RSME and MRF-3 variables.

Results

Performance

No significant main effects of attention ($F_{1, 22} = 1.31$, $p > 0.05$, $\eta_p^2 = 0.06$) or anxiety ($F_{1, 22} = 0.00$, $p > 0.05$, $\eta_p^2 = 0.00$) were found and no significant interactions. However, as shown in Figure 3, a significant main effect of group was found ($F_{1, 22} = 35.95$, $p < 0.05$, $\eta_p^2 = 0.62$) with the skilled group (15 ± 6) scoring more points than novices (5 ± 4).

Quiet Eye (ms)

No significant main effect of group ($F_{1, 21} = 0.03$, $p > 0.05$, $\eta_p^2 = 0.00$) was found nor a main effect of anxiety ($F_{1, 21} = 3.47$, $p > 0.05$, $\eta_p^2 = 0.14$), however this did approach significance ($p = 0.076$). As shown in Figure 4, a significant

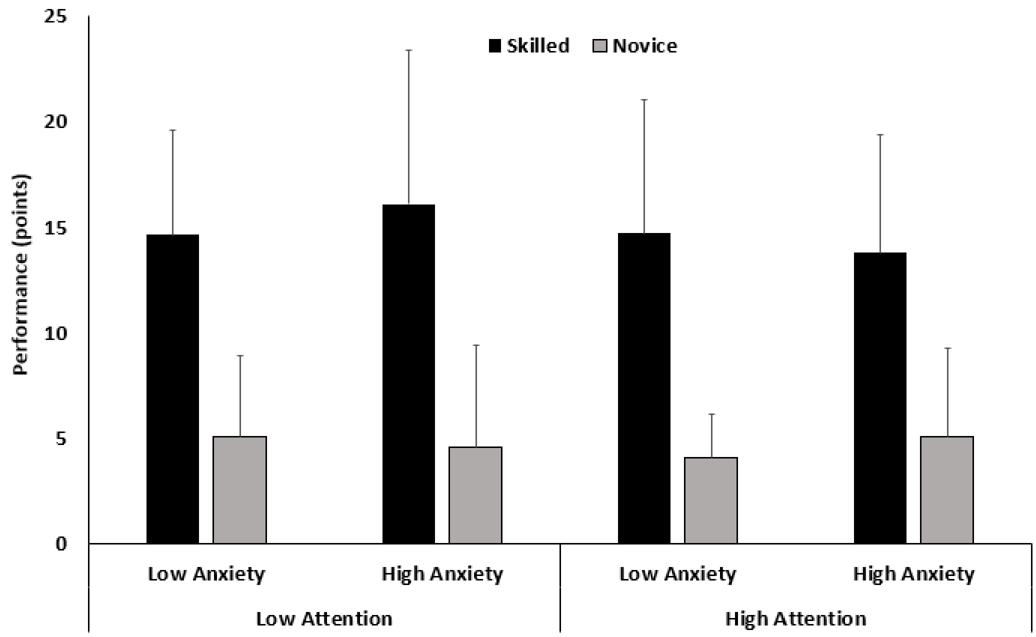

Figure 3.1. Mean Performance (points; SD) of skilled and novice groups in low attention low anxiety, low attention high anxiety, high attention low anxiety and high attention high anxiety conditions.

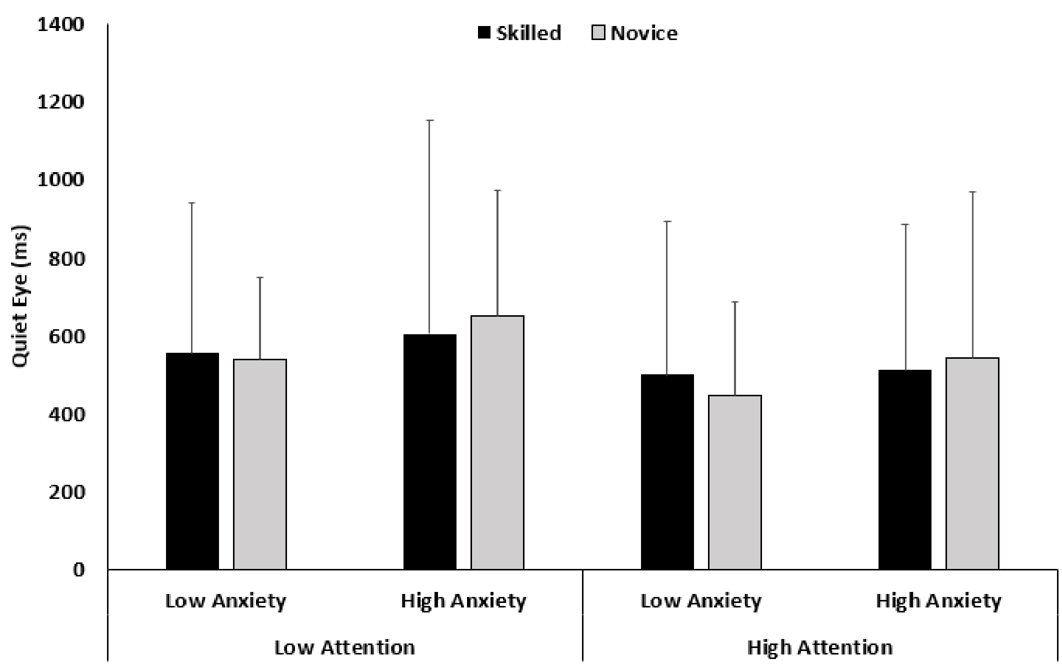

Figure 3.2. Quiet Eye (ms; SD) of skilled and novice groups in low attention low anxiety, low attention high anxiety, high attention low anxiety and high attention high anxiety conditions

main effect was found for attention ($F_{1, 21} = 5.53$, $p < 0.05$, $\eta_p^2 = 0.21$) with QE duration being significantly longer in the low attention conditions (601 ± 377ms) than the high attention conditions (511 ± 358ms).

Dual-task response accuracy

No main effect for group ($F_{1, 24} = 1.29$, $p > 0.05$, $\eta_p^2 = 0.05$) or anxiety ($F_{1, 24} = 1.68$, $p > 0.05$, $\eta_p^2 = 0.00$) were found, nor any significant interactions.

RSME

No main effect was found for group ($F_{1, 22} = 0.07$, $p > 0.05$, $\eta_p^2 = 0.00$) nor any significant interactions. However, significant main effects were found for attention ($F_{1, 22} = 56.73$, $p < 0.05$, $\eta_p^2 = 0.72$) and anxiety ($F_{1, 22} = 11.37$, $p < 0.05$, $\eta_p^2 = 0.34$). Mental effort was significantly higher in the high attention conditions (81 ± 24) than the low attention conditions (59 ± 25) and also significantly higher during high anxiety conditions (73 ± 26) than low (67 ± 27).

Cognitive Anxiety

No significant main effect of group ($F_{1, 22} = 1.54$, $p > 0.05$, $\eta_p^2 = 0.07$) was found nor any significant interactions. However, significant main effects of attention ($F_{1, 22} = 8.88$, $p < 0.05$, $\eta_p^2 = 0.29$) and anxiety ($F_{1, 22} = 6.84$, $p < 0.05$, $\eta_p^2 = 0.24$) were found. Cognitive anxiety was significantly higher for the high attention conditions (4.8 ± 1.8) than for the low attention conditions (4 ± 2.1) and significantly higher for the high anxiety conditions (4.8 ± 2.2) than for the low anxiety conditions (4.1 ± 1.7).

Somatic Anxiety

Significant main effects of group ($F_{1, 22} = 5.59$, $p < 0.05$, $\eta_p^2 = 0.20$) and attention ($F_{1, 22} = 12.66$, $p < 0.05$, $\eta_p^2 = 0.37$) were found with somatic anxiety being significantly higher for skilled (5.5 ± 1.5) than for novices (4.2 ± 2) and significantly higher for the high attention conditions (5.3 ± 1.8) than the low (4.4 ± 1.8). A significant attention by anxiety by group interaction ($F_{1, 22} = 9.94$, $p < 0.05$, $\eta_p^2 = 0.31$) was also found. Skilled participants had higher somatic anxiety across all conditions but where novices maintained similar levels of anxiety during both low attention conditions, skilled increased in anxiety from low anxiety to high. No main effect was found for anxiety ($F_{1, 22} = 3.41$, $p > 0.05$, $\eta_p^2 = 0.13$) however this did approach significance ($p = 0.08$).

Self-Confidence

No significant main effects were found for group ($F_{1, 22} = 1.32$, $p > 0.05$, $\eta_p^2 = 0.06$) or anxiety ($F_{1, 22} = 3.00$, $p > 0.05$, $\eta_p^2 = 0.12$) and no significant interactions. However, a significant main effect of attention ($F_{1, 22} = 8.65$, $p < 0.05$, $\eta_p^2 = 0.28$) was found with self-confidence being lower during high attention conditions (5.6 ± 1.8) than low attention (4.9 ± 1.8) (lower number represents more confidence).

Discussion

The aim of the current study was to investigate the effects of increased anxiety and attentional load on the performance of a basketball free-throw through the use of a dual-task paradigm and the implementation of both increased anxiety and attentional conditions. It was predicted that performance would decrease during both high anxiety and high attention conditions and that skilled participants would perform better than their lesser-skilled counterparts across all conditions. It was also predicted that the QE of both groups would significantly decrease under increased anxiety and attentional load, skilled participants would exhibit a longer QE than lesser-skilled participants and a longer QE would be associated with better performance.

It was found that participants' levels of cognitive anxiety were significantly higher during the high anxiety and high attention conditions along with a significant increase in mental effort; in addition, somatic anxiety increased during the high attention conditions whilst self-confidence reduced. These findings suggest that the manipulations of both anxiety and attention were effective whilst also reflecting the findings of similar manipulations in previous studies (Moore et al., 2012; Vine et al., 2013). However, in contrast to Runswick, Roca, Williams, Bezodis, McRobert, et al. (2018) who found that an increase in overall cognitive load through the manipulation of sport-specific context had a negative effect on performance, although the current study manipulations may have been effective, no main effects of anxiety or attention were found for performance.

As predicted, the skilled group performed significantly better than the novice group across all conditions, on average scoring 10 points more overall, yet performance across all four conditions within groups remained at similar levels. It is therefore possible that the increase in mental effort during the high attention and high anxiety conditions resulted in participants employing strategies to help negate the negative effects of the two conditions. Nieuwenhuys and Oudejans (2012) integrated model, which builds upon assumptions of Eysenck et al. (2007)'s ACT, suggests that an increase in pressure or attentional load may have a motivational effect on an individual resulting in an increase in mental effort. The authors suggest that strategies that may result in increased mental effort include attempting to ignore threat-related stimuli or attempting to reduce feelings of anxiety. Therefore, in the current study participants may have employed similar strategies that resulted in an increase in mental effort but enabled the participants to maintain performance across both the low and the high anxiety and attention conditions. Further, Nieuwenhuys and Oudejans (2012) suggest that another strategy that may result in increased mental effort is trying to enforce goal-direct behaviour.

It was predicted that a longer QE would be exhibited by skilled participants and better performance would be associated with a longer QE; whilst under increased anxiety and attentional load the QE of both groups would significantly decrease. However, no main effect of group was found for QE with both groups showing very similar QED's overall (Novice – 545ms v Skilled – 543ms). Further, no main effect of anxiety was found, with QED actually increasing from low anxiety (510ms) to high anxiety (578). It is possible that that participants' increase in mental effort in the current study was due to the use of a strategy of enforcing goal-directed behaviour, in this case their final aiming fixation, to help maintain performance under pressure, support the suggestion of Nieuwenhuys and Oudejans (2012). However, further investigation involving the reporting of explicit verbal reports is required to examine this potential association between the increase in mental effort and possible strategies employed.

Although an increase in attentional load did not result in a significant decrease in performance, the high attention conditions did in fact result in a significant reduction in QED. During the low attention conditions, participants' average QED was 588ms whereas during high attention conditions QED was 550ms. This reduction in QED under increased attentional load is similar to the findings of Nibbeling et al. (2012) who found that during a darts throwing task under high anxiety conditions, QED's were found to be shorter than during the low anxiety conditions. Further, during a secondary task, increased mental effort and a decrease in response rate was suggested by the authors to show a reduction in processing efficiency, which may have contributed to the reduction in QE duration during the high anxiety condition. This could therefore be a possible explanation for the results in the current study. Based on the principles of ACT (Eysenck et al., 2007), an increase in anxiety during the high anxiety condition may have resulted in a shift in attentional resources from task-relevant stimuli towards task-irrelevant stimuli (Corbetta & Shulman, 2002), thus a reduction in the goal-directed QE is observed due to decreased processing efficiency. As the explicit effect on the QE of increased attentional load has yet to be examined until now, it could be suggested from the current results that an increase in attentional load exerts the same negative effects on the QE as some high anxiety inducing conditions. Further, although processing efficiency may be decreased, this does not necessarily lead to a decrease in performance (Eysenck et al., 2007; Nieuwenhuys & Oudejans, 2012). As there was found to be no significant effect on performance of the attention conditions, it is possible that, in line with strategies implemented to negate the effects of increased anxiety, participants in the current study may use similar strategies to insulate themselves from the effects of increased attentional load. These strategies although using more processing resources, mean that the performer is able to maintain a similar level of performance. However, further investigation is needed to confirm this potential association.

Another possible explanation for the lack of performance differences between high and low attention conditions may be that although there was a significant reduction in QED, this reduction did not lower durations to a level that was detrimental to performance (Vickers, 1996c). It is argued that an optimum duration for the QE during aiming tasks may exist, which when met leads to optimum performance (Wilson et al., 2015). Therefore, participants in the current study may have still had sufficient time to programme a correct movement pattern to ensure a successful outcome (Vickers, 2009) or maintained a long enough QED to control the execution of the free-throw during movement (Vine et al., 2013).

The current study has identified key information that will supplement the current theoretical knowledge base. Increased attentional load has been shown to increase both anxiety and mental effort, whilst reducing QED's, a finding that has yet to be identified within the literature base. Further to this, a practical application of the results may be to train under such conditions with a view to finding potential methods by which the cognitive demands of competition can be replicated. Currently, there is an abundance of literature exploring the use of training the QE with respect to improving performance in a variety of high anxiety-inducing situations (Causer, Harvey, et al., 2014; Vine et al., 2011; Vine & Wilson, 2011). However, training under high anxiety conditions may also lead to increased performance under pressure. Alder et al. (2016) found that a six week training programme under high anxiety conditions resulted in participants demonstrating higher response accuracy and longer QE durations in a low anxiety post-test than their low anxiety trained and control counterparts. In addition, during a high anxiety post-test, the high anxiety trained group maintained response accuracy compared to the other groups, whilst when performing an on court both trained groups demonstrated greater response accuracy than the control group. Therefore, if increasing attentional load induces a similar effect on attentional resources as increasing anxiety, training perceptual-cognitive skills under these conditions may also help to improve performance under pressure whilst having the added advantage of being easier to implement.

In conclusion, the current study, through the use of a novel methodology, has extended knowledge factors affecting the QE by being the first to investigate whether an increase in attentional load exerts the same effect as increased anxiety on both the QE and performance. It was identified that increasing attentional load results in the reduction of QED and an increase in mental workload and anxiety. Therefore, although no effects were seen on performance in the current study, the potential for a dual-task training programme of similar methods, may help to recreate the cognitive workload of a competitive environment more closely than merely training under high anxiety.

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Chapter 4:

The Effect of Quiet Eye and High Attention Training on the Retention and Transfer of a Golf Putt

Abstract

The aim of the current study was to examine whether QE training under single or dual-task conditions, compared to that of traditional TT, influenced the retention and transfer of a golf putt. A three-week training programme was designed with 36 novice participants being randomly assigned into one of three groups: Low Attention QE-trained (QELA), High Attention QE-trained (QEHA) or TT. Ten pre-test golf putts from 8ft were followed by 90 (3 blocks of 30) acquisition phase putts, 10 retention putts, 10 attention transfer test putts and 10 anxiety transfer test putts. Prior to the acquisition phases, both QE groups were given instructions as to where to direct their gaze during their own putts. TT participants received the same video but with the gaze cursor removed and were given technical instructions of how to correctly swing their putter. The QEHA group was also required to perform a secondary, tone recognition task during all 90 of their acquisition phase putts. Visual behaviours, mental effort, anxiety and performance were recorded. Following training, all groups significantly reduced their performance error whilst both QE trained groups increased their QE duration from pre-test to the retention and anxiety transfer tests. However, no significant group effects were found for error or QE duration in retention or the transfer tests. Although anxiety and mental effort significantly increased during the attention and anxiety tests, only the QELA group's total QE duration was affected, with a decrease during the attention test specifically affecting the online and dwell components of the QE; however, this did not result in poorer performance. We conclude that QE training for novices has no additional benefit to performance under increased pressure and attentional load than that of traditional TT. However, training under dual-task conditions may help to negate the negative effects of increased attentional load on visual attentional control.

Introduction

Given the high-stakes nature of sport, athletes are often required to perform under intense pressure and attentional demands. Although the results of preceding chapters within this thesis have failed to replicate previous results, there is a large literature base that suggests high-anxiety inducing situations impair performance and effect the underlying perceptual-cognitive processes in aiming tasks such as archery (Behan & Wilson, 2008) and shooting (Causer, Holmes, Smith, et al., 2011; Vickers & Williams, 2007). Therefore, developing techniques to reduce the detrimental effects of anxiety may enable an individual to continue to perform at their highest level. To achieve this, the way in which anxiety affects performance must be understood and training procedures based on established theories.

A possible explanation for the effect of anxiety on performance and its underlying mechanisms is proposed by ACT (Eysenck et al., 2007). Anxiety is thought to alter the contributions of the goal-directed (top-down) system and the stimulus-driven (bottom-up) control system (Corbetta & Shulman, 2002). ACT also suggests that a decrease in processing efficiency can occur when too many resources are allocated towards identifying and nullifying a threat (i.e., stimulus-driven control), which in turn can lead to an inferior performance outcome due to a decrease in the influence of the goal-directed attentional system. Therefore, it would be beneficial to develop an effective training environment that athletes can adopt in order to help maintain a more goal-directed control during performance.

Training under heightened anxiety may be one way in which individuals learn to deal with the increased pressures of real-life anxiety-inducing situations (Nieuwenhuys & Oudejans, 2011). Through the use of a six week training programme, Alder et al. (2016) found that participants who had trained under high anxiety conditions exhibited longer QE durations and better response accuracy during a low anxiety post-test than participants trained under low anxiety and control conditions respectively. It was also reported that during a high anxiety post-test those trained under high anxiety conditions maintained response accuracy above that of the other groups, whilst during an on-court post-test, both training groups out-performed the control group. The authors suggested that this effect was due to the high anxiety trained participants becoming acclimatised to performing under increased anxiety. To manipulate anxiety for the high anxiety group, the threat of individual and team sanctions was used (e.g. sprints, push-ups). However, the threat of having to increase physical exertion is just one technique to increase anxiety during training.

Through ACT, Eysenck et al. (2007) suggest there is a fundamental link between anxiety and attention such that increasing attentional load, as with increasing anxiety, impairs the inhibition and shifting functions of the central executive. Consequently, having to perform a concurrent dual-task would result in an increase in demand for the same attentional resources, therefore the full capacity of working memory might be needed to maintain performance (Kahneman, 1973). CLT (Sweller, 1994) also suggests that total cognitive load is the sum of mental workload from three sources: intrinsic, extraneous and germane. By introducing a dual-task paradigm, the amount of extraneous load experienced by an individual who is not used to having to complete said task, would increase. However, this increase in cognitive load will only hinder performance if enough cognitive resources are used by the secondary task that sufficient resources aren't available for primary task completion. Based on ACT and CLT a dual-task paradigm should elicit the same detrimental effects on performance as high anxiety because the same resources are being allocated away from the primary task. Evidence for this was provided by Nibbeling et al. (2012), who investigated the performance of expert and novice dart players during both single and dual-task conditions in both high and low anxiety situations. In the dual-task condition, participants were required to count back from a random number between 500 and 1000 in steps of three. Novices were found to have a decrease in both performance and final fixation duration during the high anxiety conditions, whereas experts maintained similar performance levels and search strategies. Although no significant decrease in performance was found for the dual-task conditions, response rate during dual-task under heightened anxiety decreased, which further suggests that processing efficiency decreases as mental effort increases.

To further the work of Eysenck et al. (2007)'s ACT, Nieuwenhuys and Oudejans (2012) proposed an integrated model of anxiety and perceptual-motor performance. This model suggests that anxiety can have a negative effect on performance by affecting attentional control (more bias towards threat-related stimuli), but also the way in which an individual interprets and responds to information. Further, the authors suggest that increased anxiety can also have a motivational effect on an individual by increasing mental effort. Strategies that result in increased mental effort could include trying to enforce goal-directed behaviour, attempting to ignore threat-related stimuli or attempting to reduce their feelings of anxiety. Therefore, the lack of performance differences in the dual-task condition in Nibbeling et al. (2012), may have been due to individuals being motivated by the increase in anxiety and thus using strategies to maintain performance, including attempts to ignore threat-related stimuli (not responding to the count back task as frequently). Further, Nibbeling et al. (2012) found that the increase in anxiety also negatively affected the ability to maintain a steady final fixation before movement onset.

The QE period, defined as the final fixation before critical movement onset (Vickers, 1996c), has been consistently found as a perceptual-cognitive characteristic of improved performance and greater expertise in aiming tasks (Causer, 2016a) and although the results of the previous chapters have failed to replicate the robust findings of the past two decades, the QE has been associated with improved performance in multiple golf putting studies (Mann et al., 2011; Vine et al., 2013; Wilson & Pearcy, 2009). In chapter 3 it was identified that an increase in cognitive load through the introduction of a dual-task paradigm reduced the QE significantly, a finding that is yet to be identified within the literature. It is regrettable that this was not associated with the performance decrements found in previous QE studies examining the association of anxiety and the QE (Behan & Wilson, 2008), however it is important to investigate any potential mechanisms by which training procedures can be made more representative of a competitive environment.

Recently QE training has been shown to protect participants from the negative effects of anxiety in a golf putting task (Vine & Wilson, 2010). Participants who were QE trained performed significantly better in a pressure test compared to a control group, whilst also displaying significantly longer QED's from pre-test to retention. During the pressure test, although QED significantly reduced from the retention test, the QE trained group still maintained a QED long enough to guard against the effects of anxiety. Although a link between high anxiety QE training and performance maintenance has been established, whether QE training under high attention conditions elicits the same beneficial effects is yet to be investigated.

The aim of the current study was to investigate whether QE training for a golf putt under single and dual-task conditions affected the ability of participants to perform better under increased anxiety and attentional load. It was predicted that due to an increase in mental workload from external sources, both anxiety and mental effort would increase during anxiety and attention transfer tests (Eysenck et al., 2007; Sweller, 1994). We predicted that the heightened anxiety and increased mental effort during the anxiety and attention transfer tests, respectively, would negatively affect processing efficiency (Eysenck et al., 2007) resulting in a shorter QEDs. However, we predicted that QE trained participants would still exhibit a longer QED than untrained participants (Vine & Wilson, 2010). We also predicted that participants who trained under dual-task conditions would perform better in both the anxiety and attention transfer tests than those trained under single-task conditions (Alder et al., 2014). Finally, as all participants were novices, we expected performance error to decrease significantly from pre-test to retention (Vine & Wilson, 2010).

Method

Participants

Thirty-six novice golfers were recruited and each randomly assigned to either the Quiet Eye Low Attention (QELA; n = 12), Quiet Eye High Attention (QEHA; n = 12) or Low Attention Technical (TT; n = 12) training group. All participants declared that they had little to no experience in golf or golf putting (Vine & Wilson, 2010). Institutional ethical approval was gained before initiation of testing.

Apparatus

Straight, flat putts were taken on an artificial putting green to a regulation hole (10.80 cm diameter) from 8ft using a standard golf putter and a standard size (4.27 cm) white golf ball. A Tobii Pro Glasses 2 eye tracking system (Tobii AB; Stockholm, Sweden) was used to capture and record eye movements (100 Hz). All eye movement data and video footage was stored on an SD card in the wireless portable recorder unit that was worn by the participant. The SD card was then inserted into a Dell Inspiron (Dell; Texas, USA) laptop installed with Tobii Pro Glasses Analyser software allowing post-recording viewing of both the scene camera and point of gaze, represented by a circular cursor.

Measures

Quiet Eye Period

The QE period was operationally defined as the final fixation of a minimum 120ms prior to initiation of the backswing (Vine et al., 2011). QE offset occurred when the gaze deviated from the location by 1° of visual angle for more than 120ms. The QE period was not limited to the final fixation on the ball, as novice golfers may not necessarily fixate the ball at all during execution of a golf putt, whilst expert golfers have recently been highlighted to employ visual strategies that do not conclude with a final fixation on the ball. For the current study, in addition to the overall QED, the QE was split into three distinct phases as defined by Vine et al. (2013):

Pre-programming duration (QE-pre). The pre-programming phase of the QE was defined as the component of the QE starting at QE onset and ending with the initiation of the backswing. As such, this duration reflects the proportion of the QE that may be responsible for the pre-programming of the ensuing putting stroke.

Online control duration (QE-online). The online control phase of the QE was defined as the component of the QE starting with the initiation of the backswing and finishing when the putter contacted the ball, or when gaze deviated from the ball by 1° of visual angle for more than 120ms. As such, this duration reflects the proportion of the QE that may be largely responsible for the online control of the putting stroke.

Dwell duration (QE-dwell). The dwell phase of the QE was defined as the component of the QE that started when the putter contacted the ball and ended when the gaze deviated from the same location on the green by 1° of visual angle for more than 120ms. If the QE offset occurred before ball–putter contact, then dwell was recorded as zero.

A fixation was defined as a gaze maintained on an object within 1° of visual angle for a minimum of 120ms (Vine et al., 2011; Wilson & Pearcy, 2009).

Performance Error

Putting performance outcome was measured using radial error (cm), calculated from the ball's final resting place. Radial error allows the level of performance based on two dimensions (horizontal to the hole and vertical to the hole) to be measured. Shots that were holed were recorded as an error score of zero and all measurements were taken from the centre of the hole to the centre of the ball.

Anxiety

Anxiety was measured using the Mental Readiness Form-3 (MRF- 3) (Krane, 1994). The MRF-3 uses three bipolar continuous scales from 1 to 11 (worried-not worried/tense- not tense/confident -not confident) to measure three items (somatic anxiety (SA), cognitive anxiety (CA), self-confidence (SC). Participants are required to circle the number on the scale that corresponds to their feelings at a given time. MRF-3 measures were taken at the half-way point and end of each block of putts.

Mental Effort

The Rating Scale for Mental Effort Form (RSME) (Zijlstra, 1993) was used for measuring mental effort (ME). A scale consisting of a vertical axis ranging from 0 to 150, this one-dimensional form uses nine verbal anchors corresponding to a value including 0 (absolutely no effort), 75 (considerable effort), and 115 (extreme effort). Participants are asked to mark a point on the scale that indicates the ME invested in for the task performance. Again, RSME measures were taken at the half way point and end of each block of putts.

Dual-task Response Accuracy

For the current study an auditory tone response task was used as a concurrent dual-task. A random sequence of high (2000 Hz) and low (500 Hz) tones, each separated by 750ms, were made into 15-second-long clips and manually played through an iPod (Apple, USA) connected to external speakers. The participant was instructed to respond to each tone as quickly as possible with the response of either “high” or “low” depending on which tone was heard. Dual-task performance was measured as a percentage accuracy of response to the pre-set tones in each sequence. The methodology was adapted from previous dual-task measurements (Gabbett & Abernethy, 2012) and was recorded using the in-built microphone of the Tobii Eye-Tracking system..

Training Conditions

Quiet Eye Low Attention

The QELA group watched a video of an expert making the same 8ft putt, with a gaze cursor overlaid, during which they were directed to key visual behaviours. They were then given instructions derived from those given in previous studies (Vine & Wilson, 2010) on how to direct their gaze whilst taking their putts. These instructions were repeated after every 5 putts. See table 4.1 for exact instructions given.

Quiet Eye High Attention

The QEHA group watched the same video and were given the same instructions every five putts but also executed their acquisition putts while performing a dual-task. This continuous reaction time task consisted of listening to a recording of random high frequency (2,500Hz) and low frequency (500Hz) tones of 0.5s duration separated by one-second intervals. Participants were required to respond as quickly as possible to each tone by saying “high” or “low” depending on which tone they heard.

Technical Training

The TT control group were shown the same video of the expert making the 8ft putt; however, unlike the QE trained groups, the gaze cursor was not overlaid. They were then given five technical coaching points derived from those given in previous studies (Vine & Wilson, 2010) as to how to control the club and its swing during a putt. These instructions were repeated after every five putts. See table 4.1 for exact instructions given.

Transfer Tests

Attention

The attention test was a continuous reaction task similar to the high attention training condition, however the random high and low tones were separated by 0.75 seconds. Each of the 10 trials had its own 15-second clip of randomised tones.

Anxiety

Ego stressors used in previous studies (Vine & Wilson, 2010) were employed to manipulate cognitive anxiety. First, participants were told that their performance would be recorded and displayed on a leader board that would be

Table 4.1. Training instructions for both the Quiet Eye training and Technical Training groups

QE TRAINING INSTRUCTIONS	TECHNICAL TRAINING INSTRUCTIONS
Assume your stance, aligning the club so that your gaze is on the back of the ball	Stand with your legs hip width apart and keep your head still
After setting up over the ball, fix your gaze on the hole. Fixations toward the hole should be made no more than 2 or 3 times	Maintain relaxation of shoulders and arms
Your final fixation should be on the back of the ball and last for 2 to 3 seconds. This should occur before you start to putt and continue throughout the whole movement	Keep the putter head square to the ball
No gaze should be directed to the clubhead whilst taking your putt	Perform pendulum-type swing and accelerate through the ball
You should hold the same fixation on the green for 200 to 300ms after the club contacts the ball	Maintain a still head after contact

shown to all future participants. Second, a GoPro video camera was set up in front of the participant by the side of the green to record each shot. Third, participants were told that the lead researcher would be going through each trial to analyse their technique.

Procedure

As Figure 4.1 shows, a three-week training programme was designed with participants being randomly grouped into one of three groups: QELA, QEHA or TT. Week 1 consisted of a pre-test block of 10 putts, giving a baseline measurement for performance and eye movement data, and one acquisition phase of 30 putts split into two blocks of 15 putts. Week 2 consisted of two more acquisition phases of 30 putts, again both split into two blocks of 15 putts. Week 3 involved a retention test of 10 putts, identical to the pre-test and two separate transfer tests; a high attention condition and a high anxiety condition, both of 10 putts each. All groups were thanked and debriefed following the completion of the final transfer test.

Data Analysis

All trials that failed to stay on the putting green were removed from the dataset. This resulted in 324 out of 4680 (7%) trials being excluded in the radial error and QE analysis. A series of 3 Group (QELA, QEHA, TT) x 4 Phase (Pre-test, Retention, Attention, Anxiety) repeated measures ANOVAs were run to analyse radial error, total QED, QE-pre, QE-online, QE-dwell, anxiety measures and mental effort. Effect sizes were calculated using partial eta squared (η_p^2) and the α-level for significance was set at .05. If the sphericity assumption was violated, the Huynh–Feldt correction was used.

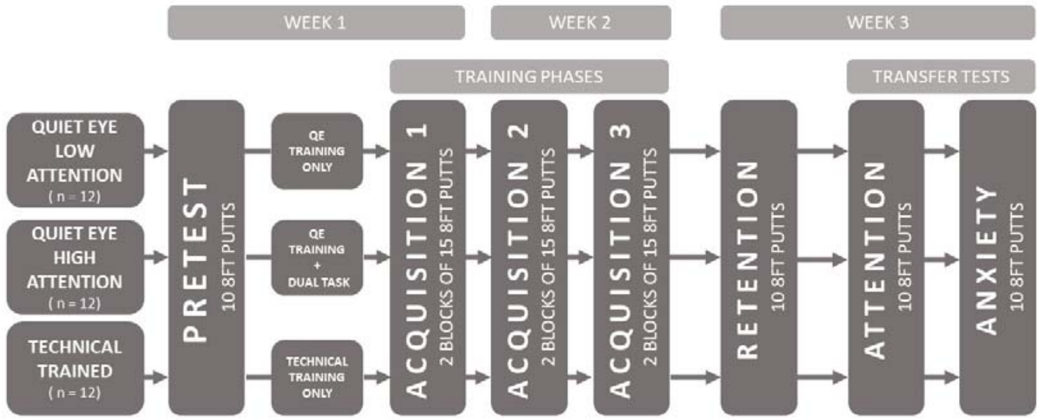

Figure 4.1. Flow diagram showing the three-visit experimental design for each group and their training procedures

Results

Pre-test, retention, attention and anxiety

Radial error (cm)

No significant main effect of group ($F_{2, 33}$ = 0.49, p = .61, η_p^2 = 0.03) and no significant group by phase interaction ($F_{6, 99}$ = 0.92, p = .49, η_p^2= 0.53) were found. However, as shown in Figure 4.2, a main effect of phase ($F_{3, 99}$ = 13.34, p < .001, η_p^2 = 0.29) was found with radial error significantly reducing from pre-test (38 ± 13 cm) to retention (26 ± 10 cm) and to both attention (28 ± 10 cm) and anxiety (27 ± 9 cm) transfer tests, see Figure 2.

Radial Error at Baseline (cm)

No significant differences between groups was found for radial error at baseline ($F_{2,33}$ = 1.65, p = 0.21, η_p^2 = 0.91).

Total Quiet Eye Duration (ms)

No significant main effect of group ($F_{2, 33}$ = 0.70, p = .50, η_p^2 = 0.04) was found. However, as shown by Figure 4.3, a main effect of phase ($F_{2.48, 81.67}$ = 15.14, p < .001, η_p^2 = 0.31) was found with QED significantly increasing from pre-test (926 ± 651 ms) to retention (1741 ± 1009 ms), attention (1412 ± 882 ms) and anxiety (1751 ± 1169 ms). A significant phase by group interaction ($F_{4.95, 81.67}$ = 3.64, p = .01, η_p^2 = 0.18) was also found, with the TT group showing no significant difference in QED from pre-test to either retention or the two transfer tests. Conversely, both QE groups significantly increased their QED from pre-test to both the retention and anxiety tests; however, whilst the QEHA maintained a similar QED in the attention test, there was a significant decrease in QED from retention for the QELA group in the attention test, see Figure 3.

QE-pre Duration (ms)

No significant main effect of group ($F_{1, 33}$ = 0.00, p = .99, η_p^2 = 0.00) and no significant group by phase interaction ($F_{2.50, 82.54}$ = 1.98, p = .09, η_p^2 = 0.11) were found. However, a significant main effect of phase ($F_{2.50, 82.54}$ = 4.05, p = .01, η_p^2= 0.11) was found with QE-pre increasing from pre-test (463 ± 451 ms), to retention (726 ± 503 ms), attention (667 ± 513 ms) and anxiety (764 ± 578 ms).

QE-online Duration (ms)

No significant main effect of group ($F_{2, 33}$ = 1.84, p = .18, η_p^2= 0.10) was found. However, a significant main effect of phase ($F_{2.71, 89.63}$ = 14.96, p < .01, η_p^2 = 0.31) was found with QE-online significantly increasing from pre-test (400 ± 303 ms) to retention (653 ± 283 ms) and the anxiety transfer (616 ± 307 ms).

QE-online also significantly decreased from retention to the attention transfer (525 ± 273 ms). A significant phase by group interaction ($F_{5.42, 89.63} = 3.33$, $p = .01$, $\eta_p^2 = 0.17$) was also found with the TT group showing no significant difference in QE-online from pre-test to either retention or the two transfer tests. Conversely, both QE trained groups significantly increased their QE-online from pre-test to both retention and anxiety test; however, whilst the QEHA maintained a similar QE-online in the attention test, there was a significant decrease in QE-online for the QELA group in the attention test.

QE-dwell Duration (ms)

No significant main effect of group ($F_{2, 33} = 1.80$, $p = .18$, $\eta_p^2 = 0.10$) and no significant phase by group interaction ($F_{3.78, 62.40} = 2.52$, $p = .053$, $\eta_p^2 = 0.13$) were found. However, a significant main effect of phase ($F_{1.89, 62.40} = 10.77$, $p < .05$, $\eta_p^2 = 0.25$) was found with QE-dwell increasing significantly from pre-test (60 ± 68 ms) to retention (362 ± 484 ms), attention (223 ± 309 ms) and anxiety (372 ± 532 ms) transfer tests.

Cognitive Anxiety

As shown in Table 4.2, a significant main effect of phase ($F_{3, 99} = 12.42$, $p < .05$, $\eta_p^2 = 0.27$) was found, with CA increasing significantly from pre-test (3 ± 1.9) to both attention (4.5 ± 2) and anxiety (4.1 ± 2) transfer tests. CA also increased significantly from retention (2.9 ± 1.2) to both transfer tests, see Table 1. Changes in anxiety were consistent across groups, reflected in a non-significant main effect of group ($F_{2, 33} = 0.30$, $p = .74$, $\eta_p^2 = 0.02$) and phase by group interaction ($F_{6, 99} = 1.75$, $p = .12$, $\eta_p^2 = 0.10$).

Somatic Anxiety

No significant main effect of group ($F_{2, 33}$ = 0.46, p = .64, η_p^2 = 0.03) was found. However, a significant main effect of phase ($F_{2.74, 90.55}$ = 7.62, p < .01, η_p^2= 0.19) and a significant phase by group interaction ($F_{5.49, 90.55}$ = 3.09, p = .01, η_p^2 = 0.16) were found. SA increased significantly from retention (3 ± 1.3) to both attention (4.4 ± 2.1) and anxiety (4.2 ± 1.8) transfer tests. Both the QEHA and TT groups reduced their SA from pre-test to retention, whereas the QELA group's SA increased. The QELA group's SA was also significantly higher for the attention test than for retention and anxiety tests, see Table 4.2.

Self-Confidence

No significant main effect of group ($F_{2, 33}$ = 1.88, p = .17, η_p^2 = 0.10) and no significant group by phase interaction ($F_{5.23, 86.23}$ = 2.10, p = .07, η_p^2 = 0.11) were found. However, a significant main effect of phase ($F_{2.61, 86.23}$ = 9.83, p < .01, η_p^2 = 0.23) was found with SC increasing significantly from pre-test (5.4 ± 2.1) to retention (4 ± 1.8). SC also decreased significantly from retention to both attention (5.3 ± 2) and anxiety (4.9 ± 2) transfer tests, see Table 4.2.

Table 4.2. MRF-3 results for Cognitive Anxiety, Somatic Anxiety and Self-Confidence, along with RSME results of Mental Effort

	PRE-TEST	RETENTION	ATTENTION	ANXIETY
COGNITIVE ANXIETY	3.0 ± 2.0 $^{*\times}$	2.9 ± 1.2 $^{*\times}$	4.5 ± 2.0 $^{\bullet +}$	4.1 ± 2.0 $^{\bullet +}$
SOMATIC ANXIETY	3.3 ± 2.0	3.0 ± 1.3 $^{*\times}$	4.4 ± 2.1 $^{+}$	4.2 ± 1.8 $^{+}$
SELF CONFIDENCE	5.4 ± 2.1 $^{+}$	4.0 ± 1.8 $^{\bullet *\times}$	5.3 ± 2.0 $^{+}$	4.9 ± 2.0 $^{+}$
MENTAL EFFORT	78 ± 22 *	55 ± 23 $^{*\times}$	80 ± 22 $^{\bullet + *}$	70 ± 25 $^{+ *}$

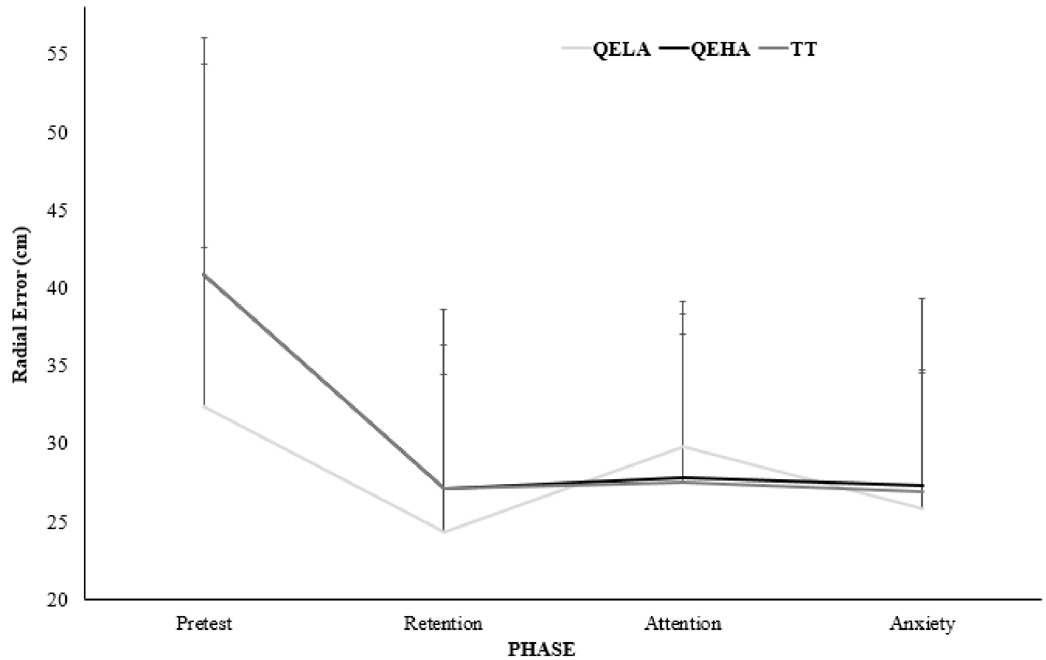

Figure 4.2. Radial error (cm) for QELA, QEHA and TT groups across pre-test, retention, attention and anxiety phases

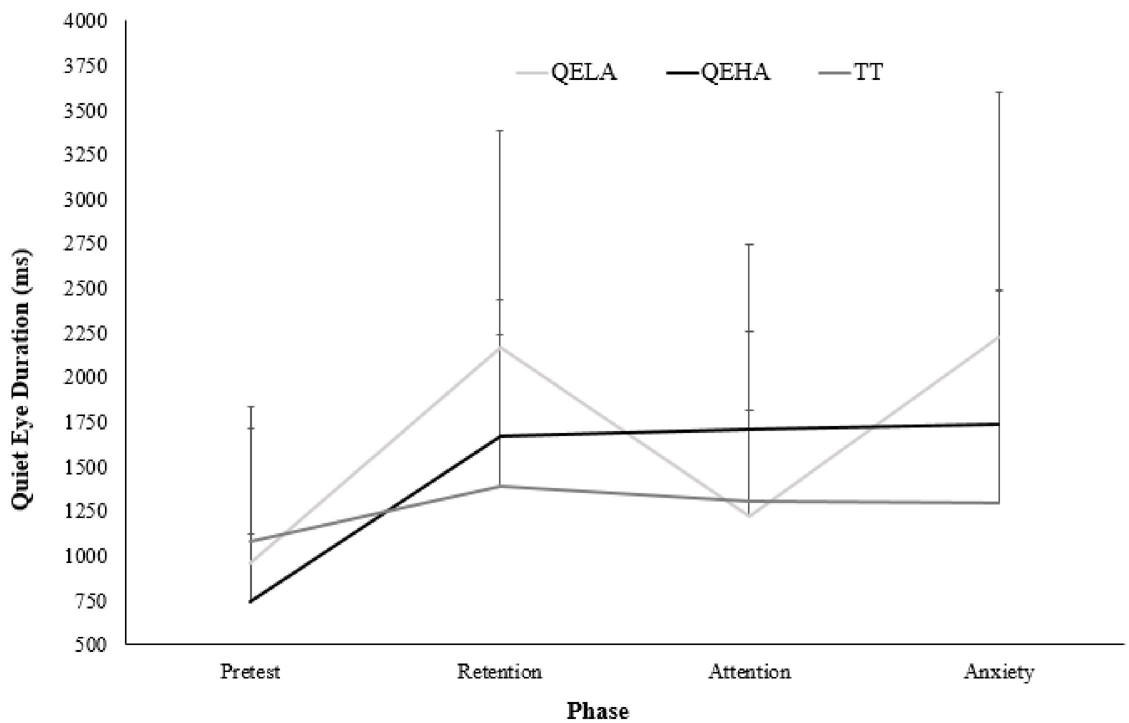

Figure 4.3. Total Quiet Eye duration (ms) for QELA, QEHA and TT groups across pre-test, retention, attention and anxiety phases

Rating Scale for Mental Effort

No significant main effect of group ($F_{2, 33} = 0.11$, $p = .89$, $\eta_p^2 = 0.01$) and no significant interaction ($F_{5.14,\ 84.73} = 0.97$, $p = .44$, $\eta_p^2 = 0.06$) were found. However, a significant main effect of phase ($F_{2.57,\ 84.73} = 18.09$, $p < .01$, $\eta_p^2 = 0.35$) was found with ME increasing significantly from pre-test (61 ± 22) to attention transfer (80 ± 22) and from retention (55 ± 23) to both attention and anxiety transfer (70 ± 25) tests, see Table 1.

Dual-Task Performance

No significant main effect of group was found for dual-task response accuracy during the high attention transfer test, with all groups averaging above 96% accuracy across all trials.

Discussion

The aim of the current study was to investigate whether QE training under single or dual-task conditions would lead to a better maintenance of performance under pressure over that of learning through traditional TT. It was predicted that due to participants being novices, performance error would significantly decrease from pre-test to retention for all groups as a result of learning. We also predicted that both QE trained groups would exhibit more efficient gaze behaviours during the attention and anxiety transfer tests, demonstrated by the maintenance of a longer final fixation before movement onset. In addition, we predicted that the QEHA trained participants would perform better during both attention and anxiety transfer tests than the QELA trained and the TT groups due to acclimatisation taking place during training.

No significant differences in performance were present for the baseline error measurements at pre-test suggesting that all groups started from a similar skill level. As predicted, performance error significantly decreased from pre-test to retention for all groups, however no group effect was found, suggesting that both QE trained groups and the TT group experienced a similar degree of learning throughout the training. This is in accordance with the findings of Vine and Wilson (2010) that after an 8-day golf putting training programme, QE and TT groups did not differ significantly in their performance during a retention test. However, it was found that the QE trained group performed significantly better than the TT group during a pressure test, a finding which has been shown in various QE training studies (Causer, Vickers, Snelgrove, Arsenault, & Harvey, 2014; Moore et al., 2012), but was not replicated in the current study. Potential reasons for this lack of group difference may owe to the population used. Due to the participants being novices, there was a large variability in the individual error scores for each group and although the QELA (24 cm) group did perform better at retention than the QEHA (27 cm) and TT (27 cm) groups, their variability was larger which may have reduced the significance of any group effects. Further, previous studies have only used two groups, QE and TT (Moore et al., 2012), whereas the current study includes a third, the QEHA group. This in turn may reduce the power of any effects seen in performance difference.

Whilst the MRF-3 and RSME data provides supporting evidence that both the attention and anxiety transfer tests significantly increased mental effort and anxiety whilst decreasing self-confidence; radial error did not significantly increase during either test. The QELA group did increase their radial error during the attention test (30cm) than the retention (24cm) and anxiety (26cm), however these were not significant differences in performance. These findings contrast with our prediction that the QEHA would perform better than both QELA and TT groups during the transfer tests. ACT (Eysenck et al., 2007) suggests that individuals may try to compensate for the negative effects of anxiety by increasing mental effort, a concept supported by the RSME results in the current study, whereby mental effort significantly increased from pre-test to the attention test and also from retention to both the attention and anxiety tests. Eysenck et al. (2007) suggest that this increase in mental effort causes a decrease in processing efficiency but does not necessarily result in a performance decrement; a suggestion that is built upon in Nieuwenhuys and Oudejans (2012)'s integrated model. This model proposes that an individual interprets situational and dispositional factors and can actively decide to increase their mental effort in an attempt to combat the negative effects of anxiety. To do so, an individual can try to re-enforce goal-directed processes or suppress the negative effects of the stimulus-driven system. The current findings therefore could be the result of both the QELA and TT groups increasing mental effort sufficiently that they were able to focus more on goal-directed processes rather than stimulus driven processes, thus maintaining their performance. However, without explicit verbal reports of behaviours the individuals engaged it, this cannot be for certain, thus further investigation in this area is needed.

We predicted that during the attention and anxiety transfer tests, total QED would reduce; however, participants in both QE trained groups would still exhibit a longer QED than the TT group, thus aiding in superior performance. In partial agreement with our original hypothesis, total QED did decrease significantly during the attention transfer test, but only for one group. Whist both the QEHA and TT groups maintained similar QED's from retention across both the attention and anxiety transfer tests, the QELA trained group's QED decreased significantly during the attention test but was maintained during the anxiety test. This finding contradicts previous QE training literature (Causer, Vickers, et al., 2014; Vine & Wilson, 2010) in that it was not the TT group whose QED reduced, but a QE trained group. It appears that by training under the high attention conditions, the QEHA group were relatively unaffected by both transfer tests. They may have become acclimatised to an increase mental workload or increased anxiety and therefore did not find the transfer tests to be a situation in which they could not perform as well. Masters (1992)'s reinvestment theory suggests that performance during heightened anxiety may increase the conscious control of movement, leading to performance decrements. However, in the current study, the TT group may have learnt a movement pattern for putting that had become more autonomous as they progressed through the acquisition phases. Therefore, when performing in the attention test under dual-task conditions, the external focus of attention may not have had a debilitating effect on performance as their putting stroke required little online attention (Beilock, Carr, MacMahon, & Starkes, 2002). Further, although the TT trained group's QED increased from pre-test to retention, attention and transfer, these differences were not significant, suggesting that any performance increase was more likely due to technique than attentional control. The QELA group on the other hand had only learnt to focus on the back of the ball during low attention conditions, so when attentional load was increased during the attention transfer, they were less able to keep their attention focused where they had been taught. This supports the predictions of ACT (Eysenck et al., 2007) in that processing efficiency was most likely reduced by the increase in mental workload. Working memory resources were then allocated away from the goal-directed system (the back of the ball) towards the stimulus-driven system (listening to the tones) and thus their QED decreased. However, due to their QE training, the QELA group were still able to maintain a fixation that was substantial enough to negate the effects of increased pressure on performance (Vine & Wilson, 2011).

In splitting the final fixation into three distinct phases, the current study continues the work of Vine et al. (2013) and Causer et al. (2017) by investigating the mechanisms by which the QE exerts its effects on attention and performance but also how the QE may be affected by increased attentional load and anxiety. Our results show that there was a significant increase in all three components (QE-pre, -online and -dwell) from pre-test to retention suggesting that as a result of the training programme all individuals became better able to focus their attention, thus keeping a steady fixation throughout the whole movement until after ball contact. However, during the attention transfer test, QE-online duration decreased significantly compared to retention and the anxiety test. Further analysis revealed a significant phase by group interaction, with the QELA group significantly decreasing their QE-online during the attention test (500 ms) compared to during retention (780 ms) and anxiety tests (772 ms), whereas the QEHA and TT groups maintained similar QE-online durations across all three phases. These findings are in accordance with Vine et al. (2013) who found that during missed putts, the components of the QE that occur during movement (QE-online) and after ball contact (QE-dwell) were significantly shorter than during holed putts. They concluded that it was this break down in attentional control once movement had been started, that led to performance decrements. In the current study, however, this reduction in the online component of the QE did not result in significant performance decrements during the attention test, As such, it is possible that even with a reduction in QE-online for the QELA group, all groups were able to maintain a sufficiently long fixation on the ball allowing for no decreases in their performance.

With no significant performance differences occurring between the groups at retention or either transfer test, it can be suggested that QE training of novices under either single or dual-task conditions provides no extra benefit above TT. Therefore, the current findings contrast with current literature. In showing that performance under pressure of a golf putt is not necessarily protected by QE training any more so than learning a robust putting technique, the results challenge a key construct of the QE training literature (Moore et al., 2012; Vine & Wilson, 2009). Further, it was revealed that whilst under heightened anxiety and attentional load, individuals can increase their mental effort which could possibly show, in accordance with predictions of Eysenck et al. (2007)'s ACT and Nieuwenhuys and Oudejans (2012)'s integrated model, they are attempting to implement strategies to negate the negative influences. However, the association between increased mental effort and protection from the negative effects of anxiety and attentional load need further, more refined investigation. Future research should therefore look to include a measure of cognitive processes, such as verbal reports, to enhance investigations into whether increases in mental effort are the result of conscious processing of strategies to overcome the increase in anxiety or attentional load. In addition, future research could also aim to extend golf putting research based around the work of Runswick, Roca, Williams, Bezodis, McRobert, et al. (2018) by investigating whether training under high attentional load can actually aid performance by decreasing the amount of conscious control an individual exerts over their movement in golf putting.

The aim of the current study was to investigate how QE training under single or dual-task conditions affected acquisition and performance under pressure and high attentional demands of a golf putt, compared to that of TT only. We found that for the QELA group, an increase in attentional workload negatively affected their total QED with a specific reduction in the online control and dwell components of the QE. However, there were no significant main effects for increased attention or anxiety on total QED or performance. Therefore we conclude that there is no benefit of QE training under either dual-task or single-task conditions over and above that of traditional technical training for novice golfers.

Chapter 5:

Epilogue

The aim of this chapter is to provide an in-depth synthesis of the work undertaken in the thesis whilst outlining both theoretical and practical implications. Prospective future directions of the research area will also be discussed.

Aims of the Thesis

The aim of the current body of work was to examine the skill-based differences in perceptual-cognitive skills in sport and further the knowledge of how factors such as task complexity, anxiety and attentional load may influence performance. In addition, the thesis aimed to ascertain whether this knowledge could be used to plan and administer a perceptual skills training programme with the view to improving performance under pressure of novice athletes. Although the effect of anxiety on the QE has been widely investigated in a range of different sports, the effects of an increase in attentional load have been somewhat neglected within the literature. Therefore, the thesis explores how these factors can affect the perceptual-cognitive skills involved in two aiming tasks, the basketball free throw and the golf putt, with a specific emphasis on skill-based differences.

Chapter 2 investigated how an increase in task complexity can affect the perceptual-cognitive skills that underlie performance of both skilled and lesser-skilled golfers, whilst also examining the link between cognitive processes, visual search, movement kinematics and performance outcome in aiming tasks. Having explored how an increase in mental workload through greater task complexity affects the QE, Chapter 3 aimed to identify whether an increase in attentional load exerts the same effects on the QE and performance as an increase in anxiety. Further, predictions of ACT (Eysenck, et al., 2007) and Nieuwenhuys and Oudejans (2012)'s Integrated Model were examined to investigate how anxiety and attentional load influence processing efficiency and performance effectiveness. Finally, in Chapter 4 the knowledge gained from the previous chapters and previous literature was used to test the creation of two QE training programmes. The effects of training under single and dual-task conditions on retention and performance under high anxiety and attentional load were compared to that of a traditional technical training programme. As a whole, the thesis aimed to extend the current literature on the effects of increased attentional load on perceptual-cognitive skills and performance in aiming tasks, whilst investigating whether novel training methods could be used to improve performance under pressure.

Summary of key findings

In Chapter 2, a sample of expert and near-expert golfers were required to perform a series of simple and complex short game shots (chips and putts). The aim of the chapter was to investigate whether expertise level and an increase in task complexity affected performance, visual search strategies and club kinematics. During the first experiment, participants had to putt in both straight and breaking conditions from three distances of 3ft, 8ft and 15ft. Contrary to previous findings, the near expert group exhibited a significantly longer total QED than the expert group during the putting task. This difference was underpinned by the near-experts having a QE-pre duration of more than double that of the experts (1490ms v 709ms). However, when examining cognitive processes, there was no significant difference in the number of gathering information or planning statements generated between the groups, suggesting that they both ‘read the green’ and planned their actions similarly. In addition, no significant difference was found for performance error between groups suggesting that the mediating factor between the groups may have been the increase in QE-pre for the near-experts allowing them to perform at a similar level to the experts.

In contradiction to our predictions, although error significantly increased from straight to breaking and in line with distance, total QED did not increase significantly, suggesting that an increase in task complexity does not necessarily lead to increase in QED. It was found however, that during 3ft and 15ft breaking putts, QED was reduced compared to the corresponding flat putts; but for 8ft breaking putts, QED was increased. Again, underpinning this difference was the contribution of the QE-pre. Across all three distances, the expert group maintained a similar QE-pre in both straight and breaking conditions. However, the near-expert group reduced their QE-pre for 3ft and 15ft breaking putts but increased it for 8ft. This may be a reflection of a perceived harder putt for the 8ft distance and again couples with the gathering information and planning statement findings. In addition, however, a significant increase in reflection statement generation was found during the breaking putts. This was underpinned by a significant main effect of group, with the experts generating significantly more reflection statements than the near-experts. This suggests that they were better able to use the information about previous putts to inform their subsequent attempts, therefore they may not have needed to plan their movements for as long, resulting in a shorter QE-pre.

In the second experiment, participants were asked to perform chip shots from 20ft, 30ft and 75ft, again in both straight and breaking conditions. As with the putting task, performance error significantly increased from straight chips to breaking and in line with distance, suggesting that the tasks were increasingly more complex and thus harder to complete. However, again no significant differences in total QED were found for slope, distance or group. There was nevertheless a significant main effect of distance on the QE-dwell component of the QE. During the 20ft chips, QE-dwell was significantly longer than during the 30ft and 75ft chips. This could therefore be considered as a potential reason for increased error with distance. If an individual is not maintaining a steady fixation on the back of the ball through to ball contact, the quality of the impact between the clubface and the ball may be reduced and therefore lead to a detriment in performance. Additionally, hypotheses for QED's during chipping were based on previous golf putting literature and may not have accounted for the more highly skilled population used in the chapter.

Chapter 2 provided an insight into how expertise level and increased task complexity may affect visual attention and the cognitive processes that underpin performance under increased mental effort. The identification of a longer QE-pre for a task that is perceived as more complex, and therefore more cognitively demanding, provides a basic understanding of the mechanisms that underpin performance of highly skilled individuals who are yet to progress to expert level. In order to gain further understanding of how an increase in cognitive workload affects perceptual-cognitive skills and therefore performance, the examination of an aiming skill in such conditions was devised.

In Chapter 3, the associations of increased attentional load, perceptual-cognitive skills and performance were investigated further by introducing a novel dual-task paradigm during a basketball free throw, coupled with both high and low anxiety conditions. A sample of novice and skilled basketball players were required during high attention conditions to complete 10 standard basketball free-throw shots whilst continuously responding to either high (2000 Hz) or low (500 Hz) tones played at 750ms intervals. During the high anxiety conditions, participants completed 10 free throws after a series of ego-stressors such as being filmed and the possibility of monetary rewards for the best performance were administered. As with Chapter 2, visual attention was measured using total QED, whilst additional measures of mental effort and anxiety were recorded using the Rating Scale for Mental Effort (RSME) and Mental Readiness Form (MRF-3) forms, respectively. Performance was measured using a 3-point system that distinguished between clean shots and those which involved varying levels of execution error.

Results of the RSME and MRF-3 revealed that the manipulations of both attention and anxiety were successful, with participants reporting higher levels of mental effort, cognitive anxiety and somatic anxiety during the high compared to the low attention conditions. Participants also reported higher levels of mental effort and cognitive anxiety during the high anxiety conditions compared with the low. In addition, the MRF-3 revealed skilled participants reported higher levels of somatic anxiety than novices, whilst also revealing a significant group by attention by anxiety interaction, whereby the skilled group increased their somatic anxiety for the low attention, high anxiety condition whereas the novices maintained a similar level. This however did not influence overall performance with the skilled group scoring significantly more points than the novices.

Unlike Chapter 2, no main effect of group was found for total QED. However, QED was found to be significantly longer in the low attention conditions than the high. This result coupled with the RSME data suggests that an increase in mental effort resulted in a decrease in processing efficiency during the high attention conditions. Nevertheless, a decrease in processing efficiency does not necessarily lead to a detriment in performance effectiveness, if the correct coping mechanisms are in place. Performance of both groups in low and high attention conditions was very similar, suggesting that although processing efficiency may have been compromised, performance effectiveness was not. Therefore, although the novices scored significantly less points than the skilled participants across the four conditions, this may have been due to a lack of technical ability rather than the ability to stay focused when aiming.

With the results of Chapter 3 showing that an increase in attentional load can exert similar effects to an increase in anxiety on both perceptual-cognitive skills and physiological factors, the logical progression was to investigate how this information could inform a training programme to improve performance under pressure. As such, in Chapter 4 thirty-six novice golfers were split equally into three training groups. The QELA group for their training watched a video of an expert making a putt, with eye movement cursor overlaid, and were then directed to key visual behaviours. In addition, they were given five instructions on how to direct their gaze during their putts. The QEHA group received the same training but had to perform a secondary tone reaction task whilst taking their putts. This involved a random series of high and low tones being played continuously throughout their putt, to which they had to respond verbally with 'high' or 'low'. The TT group for their training watched the same expert putting video but without the gaze cursor overlaid. They were directed to key technical points during the putt and given five technical instructions. Over three visits participants completed a pre-test, three acquisition phases, a retention test and two additional transfer tests, high attention and high anxiety. Throughout the training programme radial error as a measure of performance was recorded along with eye movements, RSME and MRF-3 measures as in previous chapters.

Similar to Chapter 3, the RSME and MRF-3 revealed that cognitive and somatic anxiety significantly increased from the retention test to both transfer tests whilst self-confidence decreased significantly. In addition, mental effort also increased significantly from retention to the transfer tests suggesting that our manipulations of both attention and anxiety were successful. Concerning eye movements, total QED significantly increased from pre-test to retention and to both transfer tests yet a significant phase by group interaction revealed that the TT group maintained a similar QED throughout all phases, whilst both QE trained groups significantly increased their total QED from pre-test to retention and anxiety transfer test. However, during the attention transfer test, the QELA significantly reduced their total QED whereas the QEHA maintained similar durations as at retention and anxiety tests. This reduction in total QED was underpinned by a reduction in the QE-online component of the final fixation, which indicates that the increase in mental effort decreased processing efficiency and therefore resulted in the QELA trained participants being unable to hold a steady fixation throughout the movement phase of the putt until ball contact. Nevertheless, as with Chapter 3, this reduction in attentional control did not result in a significant performance detriment. Radial error significantly reduced from pre-test to retention and both transfer tests, showing that all groups improved their performance after training. However, although during the attention test, the QELA group did exhibit a radial error of around 4cm more than the other two groups, this difference was not significant. It could therefore be suggested that although the reduction in total QED and specifically the QE-online component did result in slightly worse performance, participants may have been able to hold a steady fixation of long enough duration to perform to a similar standard as the other groups.

Implications for Theory and Practice

As the previous section provided a summary of the key findings from Chapters 2, 3 and 4, the current section will aim to provide the possible implications of these findings for both theory and practice.

Quiet Eye

The QE has been associated with the underpinning of expert performance in various aiming and interceptive tasks such as shooting (Causer et al., 2010; Vickers & Williams, 2007), basketball (Harle & Vickers, 2001; Oudejans, van de Langernberg, & Hutter, 2002; Vickers, 1996b) and golf (Klostermann, Kredel, & Hossner, 2014; Vickers, 1992, 2004). Further, a longer QE has consistently been linked with better performance (Behan & Wilson, 2008) (Williams, Singer, et al., 2002), whilst more recently a longer duration of the QE-pre and QE-online components of the total QE fixation have also been associated with better performance (Causer et al., 2017; Vine et al., 2013). It is therefore assumed that the QE serves either a pre-programming of movement function, an online control of movement function or a combination of both.

In contrast to the previous literature, the findings across both Chapters 2 and 3 suggest total QED may not to be a performance variable that can differentiate between more expert performance. In Chapter 3, no expertise differences were found for the QE, whereas in Chapter 2 during the putting task, the opposite of previous findings was revealed with near-experts exhibiting a significantly longer total QED than their expert counterparts. This difference was underpinned by a QE-pre of more than double that of the expert group. It has previously been hypothesised that the QE may allow for a critical period of time before movement onset in which the movement parameters for the task at hand can be programmed (Moore et al., 2012). During a golf putting task, individuals must programme the correct movement pattern to strike the ball in the correct part of the clubface for optimum contact whilst also monitoring the force by which they strike the ball. It has been found that as golfers progress through the stages of learning towards becoming more expert, they become more consistent in finding the centre of the clubhead when putting (Pelz, 2000). This allows for a better contact between the putter and the ball, which in turn enables a higher percentage of the forces produced by the arm swing to be transferred to the ball. Therefore, in Chapter 2, due to a possible deficiency in skill compared to the expert group, the near-experts may have compensated with a longer QED as they had to plan their movements for longer for both straight and breaking putts. However, there were no differences in performance between groups found in Chapter 2. It is possible that the near-experts may have been able to utilise an extended QE period, specifically increasing their QE-pre component, to plan a more effective movement pattern, thus resulting in performance being elevated to a similar standard as the expert group, supporting previous findings that an extended QE is associated with better performance; however, without post-performance questioning or specific instructions to provide verbal reports about whether individuals were consciously trying to concentrate more, we cannot be certain.

It has also been suggested that the findings of previous QE research are somewhat paradoxical (Klostermann & Hossner, 2018). Experts are generally characterised by an ability to economise their motor processing yet display a longer QE than lesser-skilled individuals. Although Klostermann et al. (2014) suggest this increase may be due to an inhibition process, the results of Chapter 2 are in line with the economisation approach (Mann et al., 2016). Experts already possess the necessary technique for performance completion, which is performed autonomously, therefore they only need to programme the power of their shot. On the other hand, lesser-skilled individuals, for instance the near-expert group, potentially may need to actively programme the technique of their putting swing in addition to factors such as power and as such need to extend the pre-programming period of the QE. In addition, the issue of task complexity may affect the duration of the QE due to perception of the task at hand. If an individual perceives the task as easy, then they may feel they do not need to employ their ‘usual’ approach in terms of visual attention. The expert participants may have perceived a 3ft putt as an easy task and thus did not maintain a long QE on the back of the ball as they felt they did not need to.

Another possible explanation for the lack of replication of previous findings may be some of the measures used in the current thesis. Previous studies have used success as an outcome measure for performance when investigating the QE (Causer et al., 2010), whereas in the chapters two and four a graded system of radial error is used, providing a more sensitive measure of performance. This does however lend itself to the potential for conflicting results with previous literature. Where a golf putt with an error of 1cm may be interpreted as relatively successful performance for the one study, this may be counted as unsuccessful for another. It is therefore important for future studies to endeavour for a universal measure of performance in golf putting tasks to allow for easier comparison, interpretation and replication of results (Baker & Wattie, 2016).

Anxiety effects on the QE

The QE has previously been shown to be negatively affected by increased anxiety (Behan & Wilson, 2008; Causer, Holmes, Smith, et al., 2011). The causal mechanisms behind a reduction in QED due to increased anxiety have thus far been explained through predictions of PET (Eysenck & Calvo, 1992) and more recently those of ACT (Eysenck et al., 2007). Both theories predict that as state anxiety increases, attentional resources are allocated away from task-relevant stimuli (goal-directed control) and towards more task-irrelevant stimuli (stimulus-driven control) resulting in decreased processing efficiency (Corbetta & Shulman, 2002). ACT builds upon PET in that the authors suggest that worrisome thoughts associated with increased anxiety consume attentional resources in the working memory and therefore fewer resources are available for primary task completion. Further to this, Eysenck and colleagues suggest that an increase in anxiety can also have a motivational effect in which increased effort may be stimulated and other additional processing resources and strategies may be employed.

The findings of Chapter 3 again contradict those of previous studies. Although measures of anxiety confirmed the manipulation was indeed successful, participants' QEDs actually increased from low to high anxiety. One possible reason for this phenomenon may be explained using Nieuwenhuys and Oudejans (2012)'s Integrated Model of Anxiety and Perceptual-Motor Performance. This model furthers the suggestion of ACT that an increase in anxiety may provide a motivational function for an individual. The authors suggest that this may enable them to try and enforce goal-directed behaviours, actively inhibit stimulus-driven responses or attempt to reduce feelings of anxiety. Therefore, in Chapter 3 during the high anxiety conditions, participants may have actively attempted to enforce a goal-directed behaviour, namely the final fixation on the target before movement onset, in order to negate some of the negative effects of anxiety. This as such resulted in an extended QED compared to during the low anxiety conditions. Nieuwenhuys and Oudejans

(2012) agree in line with predictions of ACT that these strategies may result in decreased processing efficiency due to an increase in mental effort, as was found in the RSME results of Chapter 3.

ACT suggests that increased anxiety can affect not only processing efficiency but also performance effectiveness. However, if compensatory strategies are in place, then detriments to performance may be avoided. In Chapter 3, although their processing efficiency was decreased as explained above, it is possible that by increasing QEDs from low to high anxiety conditions, participants were potentially able to maintain a similar level of performance. This effect was shown in elite biathlon athletes, whereby under increased anxiety and physical exertion, those athletes who increased their QED above that of a low anxiety condition, were able to maintain their performance (Vickers & Williams, 2007).

The results set out in Chapter 3 help to support the assumptions of ACT and Niewenhuys and Oudejans integrated model by providing further evidence that individuals may actively negate some of the negative effects of anxiety by implementing auxiliary strategies. These strategies may enable attentional focus to be maintained, in turn allowing sufficient time for programming of successful movement patterns.

Attention and the QE

Although there have been numerous studies investigating the effect of increased anxiety on perceptual-cognitive skills and sports performance, there has been somewhat of a paucity in the literature examining the role of increased attentional load. ACT proposes that there is a central link between anxiety and attention with an increase in attentional load impairing the inhibition and shifting functions of the central executive. This may lead to individuals becoming distracted by irrelevant stimuli during performance and therefore being unable to maintain a steady focus of attention. Further, one prediction of ACT is that as tasks demands on the central executive increase, the negative effects of anxiety are exaggerated.

In Chapter 3, results showed that during high attention conditions, QED was found to significantly decrease. It therefore seems that an increase in attentional load results in participants being unable to control their attentional focus as effectively. As participants were having to complete a secondary tone-response task whilst taking their shots, attentional resources will have been allocated to responding accurately and as such reduced the number of resources engaged in the primary task. This, as in the high anxiety conditions, resulted in decreased processing efficiency, but in contrast led to the decrease in QED. The additional demand of the dual-task may have limited the potential of the compensatory mechanisms employed in high anxiety conditions to maintain attentional focus. In addition, participants may have been less able to control their gaze from shifting to irrelevant stimuli during performance due to the impairment of the shifting and inhibition functions of the central executive (Eysenck et al., 2007).

However, although a decrease QED was observed, again a reduction in performance effectiveness was avoided. It is possible that although QED did decrease, participants were still able to maintain a fixation duration sufficient to programme the correct movement parameters for adequate performance. Previously, QEDs of around 900ms for elite and 350ms for near-elite basketballers have been identified (Vickers, 1996a), suggesting that during the high attention conditions, with participants QEDs of around 500-600ms, this was a sufficient amount of time to programme effective movement patterns.

Chapter 3 furthers previous research into the assumptions of ACT by investigating the specific effects of increased mental workload on attentional control and performance. The results provide clear evidence that increases in attentional load produce similar effects as increases in anxiety levels. It appears that the same mechanisms that underpin attentional control are affected by increases in mental workload and can lead to a detriment in processing efficiency. Further, although not shown in the results of Chapter 3, it is possible that increases in mental workload could lead to decreased performance effectiveness if the correct compensatory mechanisms are not in place. As such, the findings of the chapter allow new and innovative training processes to be developed with the aim of insulating individuals from increased pressure during performance.

QE Training

QE training programmes have recently been found to be beneficial for performance, as discussed in Chapter 1. In particular, the effects of QE training on performance and attentional control during aiming tasks has been examined with the view to improving performance under increased pressure (Moore et al., 2012; Vine & Wilson, 2009). Further, training under increased anxiety levels has also been investigated. However, due to the changeable nature of sporting competition, recreating the pressures and therefore the anxiety levels experienced by individuals is challenging. Previous studies have utilised ego stressors such as filming of participants, possibility of monetary rewards and incongruent feedback to evoke the increased levels of anxiety during training.

Yet, a major limitation of these methods is that individuals may perceive the stressors in different ways, such as a challenge or a threat. As such, not all participants may have exhibited the same responses meaning the external validity of the studies could be somewhat reduced. In addition, there has yet to be a study that links QE training and training under increased pressure.

Having identified in Chapter 3 that an increase in attentional load exerts similar effects on an individual's QE as increased anxiety has been shown to do previously (Behan & Wilson, 2008), Chapter 4 aimed to test a novel method of training individuals under conditions that elicited similar effects as a competitive environment. Unlike previous QE training studies, the use of two different QE training groups, a technical trained control group and both high attention and high anxiety transfer tests, allowed for a more sensitive measure of intervention effectiveness. In having high attention and low attention QE trained groups, this enabled a focus on QE training value but also the influence of dual-task conditions for training in general. However, it was not only important to focus on the effectiveness of the QE interventions compared with each other, but also compared to a traditional method of training. Previous studies have only used one QE group and one TT group as a control, therefore any significance in variables between the two groups was clear. The current methodology allowed a more in-depth analysis to occur compared with previous methodologies and as such enabled the findings to be more specifically applied in the future.

The findings of Chapter 4 are summarised above, but to review; all groups significantly improved their performance from pre-test to retention, yet there were only significant increases in total QED for the low attention and high attention QE trained groups. The TT group although they increased their QED slightly from pre-test to retention and transfer tests, this was not to the extent of the QE trained groups. Further, a significant phase by group interaction was found for total QED, with the TT and QEHA groups maintaining similar QEDs across retention, attention transfer and anxiety transfer tests, but the QELA group significantly reducing their QED during the attention test when compared to retention and anxiety transfer. This reduction was underpinned by a reduction in the QE-online component of the final fixation. There were no significant differences in performance between groups at either retention or the transfer tests. Overall, the findings suggest that QE training under dual or single task conditions has no performance benefit over and above that of traditional technical training.

Chapter 4 provides an exploratory investigation into an area of QE training which to date, is yet to be explored, the use of dual-task or high attentional load to increase pressure during training. The findings not only extend the research into QE training, but also provide new evidence that QE training may not be a suitable tool for significant improvements in performance over TT in novices. The results suggest that novices may simply need to learn the technical aspects of performance before engaging in more advanced perceptual skills training. Previous studies have used samples of skilled or elite golfers who will have possessed the necessary movement patterns for successful performance before learning how to control their attentional focus. Therefore, the performance benefits previously shown may be a result of an additional mechanism that assists in a system that is already working well. In addition, the findings suggest that the use of a dual-task paradigm for skill acquisition in golf may not be of any benefit when coupled with QE training.

Future Research

With perceptual skills training having been shown to improve performance in a range of skills over recent years, it is important to continually adapt training processes to reflect new findings within the literature. Currently, QE training programmes focus on the ability of such interventions to improve performance under pressure, yet training under conditions of high anxiety has scarcely been examined. Chapter 4 aimed to address this limitation in the current literature, but further investigations are required to study the effects of training under pressure in different populations and different skills. As discussed in the previous section, Chapter 4's findings suggest that QE training under increased attentional load provides a benefit for attentional control but does not necessarily result in a performance advantage for novice golfers. Therefore, examination of skilled golfers under the same conditions would provide an extension of the study's findings whilst also supplementing the literature concerning optimal practice conditions for improved performance. Further, the use of similar training programmes in other sports and skills would provide greater understanding of QE training under dual-task or high pressure conditions.

Currently, QE training studies have on the whole used shorter term interventions including one session (Vine et al., 2011), three session (Moore et al., 2012) and eight session (Causer, Holmes, & Williams, 2011) protocols. However, although these studies provide evidence for the effectiveness of QE training in the short term, the retention of the benefits gained through the intervention are unclear in the long term. Chapter 4's findings suggest that QE and dual-task training can aid with the maintenance of attentional control under high attentional load. As such, the application of a training programme using similar techniques but over an extended period, such as a year, may enable individuals to better retain the benefits and therefore result in an improvement in performance long term. Harle and Vickers (2001) reported that individuals that had been QE trained improved their free throw performance in competitive matches, but only after a sustained QE training programme. After the first season of QE training, although perceptual characteristics such as an extended QE were present, the effects on performance in competition were not. It was only after continued practice that these performance improvements were shown. Therefore, similar effects may be found in dual-task QE training if done over an extended period.

Summary

To conclude, the findings contained within the current thesis have provided an analysis of the effects of increased anxiety and attentional load on the QE period and performance in aiming sport. The research has furthered current literature by examining a previously unexplored area of perceptual-cognitive skills and presented evidence suggesting that manipulations of attentional load may exert similar effects on the QE as increased anxiety.

However, the thesis challenges currently held views that the QE is associated with increased performance and that QE training can help to negate the negative effects of anxiety on performance. Overall, the results have both theoretical and practical implications within the area of the QE and representative training conditions, whilst providing a foundation for future research.

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