Anxiety and attentional control in football penalty kicks: A mechanistic account of performance failure under pressure

Submitted by Greg Wood to the University of Exeter

as a thesis for the degree of

Doctor of Philosophy in Sport and Health Sciences

In November 2010

This thesis is available for Library use on the understanding that it is copyright material and that no quotation from the thesis may be published without proper acknowledgement.

I certify that all material in this thesis which is not my own work has been identified and that no material has previously been submitted and approved for the award of a degree by this or any other University.

Signature: …………*G. Wood*………………………..

Abstract

Football penalty kicks are having increasing influence in today's professional game. Despite this, little scientific evidence currently exists to ascertain the mechanisms behind performance failure in this task and/or the efficacy of training designed to improve penalty shooting. In a football penalty kick it has been reported that the majority of kickers do not look to the area they wish to place the ball; preferring to focus on the 'keeper and predict anticipatory movements before shooting. Such a strategy seems counterproductive and contradictory to current research findings regarding visually guided aiming. Coordination of eye and limb movements has been shown to be essential for the production of accurate motor responses. A disruption to this coordination not only seems to negatively affect performance, but subsequent motor responses seem to follow direction of gaze. Thus, where the eyes lead actions tend to follow. In study 1, ten participants were asked to kick a standard sized football to alternate corners of a goal, whilst looking centrally and whilst looking where they intended to hit. This disruption of eye-limb coordination brought about a 15% reduction in kicking accuracy. When participants were asked to fixate centrally, their shots hit more centrally (17cm) than when they were allowed to look where they intended to hit. These results were in spite of no significant differences between the number of missed shots, preparation time and ball speed data across conditions. We concluded that centrally focused fixations dragged resultant motor actions inwards towards more central target locations. Put simply, where the eyes looked shots tended to follow. The second study sought to test the predictions of attentional control theory (ACT) in a sporting environment in order to establish *how* anxiety affects performance in penalty kicks. Fourteen experienced footballers took penalty kicks under low- and high-threat counterbalanced conditions while wearing a gaze registration system. Fixations to target locations (goalkeeper and goal area) were determined using frame-by-frame analysis. When anxious, footballers made faster first fixations and fixated for significantly longer toward the goalkeeper. This disruption in gaze behaviour brought about significant reductions in shooting accuracy, with shots becoming significantly centralized and within the goalkeeper's reach. These findings support the predictions of ACT, as anxious participants were more likely to focus on the "threatening" goalkeeper, owing to an increased influence of the stimulus-driven attentional control system. A further prediction of ACT is that when anxious, performers are more likely to be distracted, particularly if the distracter is threat related. When facing penalty kicks in football (soccer), goalkeepers frequently incorporate strategies that are designed to distract the kicker. However, no direct empirical evidence exists to ascertain what effect such visual distractions have on the attentional control, and performance, of footballers. In the third study, eighteen experienced footballers took five penalty kicks under counterbalanced conditions of threat (low vs. high) and goalkeeper movement (stationary vs. waving arms) while wearing eye-tracking equipment. Results suggested that participants were more distracted by a moving goalkeeper than a stationary one and struggled to disengage from a moving goalkeeper under situations of high threat. Significantly more penalties were saved on trials when the goalkeeper was moving and shots were also generally hit closer to the goalkeeper (centrally) on these trials. The results provide partial support for the predictions of attentional control theory and implications for kickers and goalkeepers are discussed. The previous studies showed that anxiety can disrupt visual attention, visuomotor control and subsequent shot location in penalty kicks. However, optimal visual attention has been trained in other far aiming skills, improving performance and resistance to pressure. In study 4, we therefore asked a team of ten university soccer players to follow a quiet eye (QE; Vickers, 1996) training program, designed to align gaze with aiming intention to optimal scoring zones, over a

seven week period. Performance and gaze parameters were compared to a placebo group (ten players) who received no instruction, but practiced the same number of penalty kicks over the same time frame. Results from a retention test indicated that the QE trained group had more effective visual attentional control; were significantly more accurate; and had 50% fewer shots saved by the goalkeeper than the placebo group. Both groups then competed in a penalty shootout to explore the influence of anxiety on attentional control and shooting accuracy. Under the pressure of the shootout the QE trained group failed to maintain their accuracy advantage, despite maintaining more distal aiming fixations of longer duration. The results therefore provide only partial support for the effectiveness of brief QE training interventions for experienced performers. This series of studies are the first to explore the gaze behaviour of football penalty takers in a quest to uncover and understand anxiety's negative influence on attentional control and performance. They are also the first to explore the efficacy of goalkeeper distractions and training in improving performance from both the goalkeeper's and kicker's perspective. The results of these studies conclude that when anxious, penalty takers show an attentional bias toward the 'threatening' goalkeeper that can be increased and utilised by a goalkeeper employing distraction techniques and that penalty takers do benefit, to some extent, from a gaze-based pre-shot routine.

Acknowledgements

First, a deep felt thanks to my supervisor Dr. Mark Wilson for all his help on every aspect of this thesis, and also for his supervision on my BSc and MSc projects whist at Manchester Metropolitan University. I literately couldn't have done this without your guidance, trust and understanding - particularly in relation to me travelling to Exeter whilst living in Stoke. Thanks – I really appreciate everything you've done!

I would also like to thank my fellow PhD student, Sam Vine, for our helpful chats and his assistance with data collection. Thanks mate!

I would also like to thank both my parents and the in-laws for their help in making this all possible. Thanks for your support with the children whilst I have been in Exeter and also for your support, financially and emotionally, to both me and Heather, throughout this whole process. You are all very much appreciated and loved!

A heart-felt thanks to my long-suffering partner, Heather. The support you have shown me throughout this process, from the college days to this point, has been phenomenal and extremely moving! Indeed it would take another manuscript of this length just to cover everything you've done and the thanks and gratitude that I feel you're owed. I love you!

And finally, thanks to my two boys Reis and Jacob for offering me a welcomed (sometimes anyway) distraction away from writing this thesis. Remember, you can achieve anything if you put your mind to it! I'm extremely proud of you both and love you very much!!

Post viva thanks also go out to my external examiner Prof. Mark Williams and internal examiner Dr Paul Freeman. I enjoyed our discussions and appreciate your insightful comments and suggestions. Your friendly approach made the whole experience extremely enjoyable (at least retrospectively!). Thank you.

Contents

Tables

Figures

Chapter 1: Theoretical Issues Surrounding Performance Failure in Penalty Kicks

Introduction to Penalty Kicks

In football (soccer), penalty kicks play a pivotal and decisive role in the outcome of many important matches at both national and international level. In fact, of the 145 goals scored in the 2010 World Cup finals, 22% came from the penalty spot (Fifa.com). A penalty kick is either awarded for various infringements that take place within the 18 yard box or a penalty shootout is utilised at the end of regulation time to break the deadlock in tied games. It is a situation where only two protagonists are involved – the shooter verses the goalkeeper. The shooter is required to take a shot and attempt to score from a distance of 11 metres from the centre of a goal. The goal area measures 24ft wide by 8ft high, giving a total target area of approximately 192ft^2 for the kicker to hit.

Performance Success in Penalty Kicks

A penalty kick is fundamentally an aiming skill requiring the shooter to shoot the ball past the goalkeeper, who stands centrally striving to prevent the player from scoring. It stands to reason that a ball placed further from the goalkeeper's reach stands a better chance of beating the goalkeeper, resulting in a successful shot. It is a well-known premise among coaches that the optimal place to kick a penalty is on the ground, as close as possible to the goalpost. This intuitive assumption is believed to be true because the reaction time that the goalkeeper has is very short, and therefore it should be almost impossible for him or her to save a well-placed ball directed to that location (Dohmen, 2008).

Bar-Eli and Azar (2009) analysed 286 penalty kicks in an attempt to identify the optimal area of the goal that offers the highest probability of scoring. The analysis revealed that no kick towards the upper third of the goal was stopped, while 12.6% of the kicks to the middle third and 19.8% to the lower third were stopped by the goalkeeper. These results suggest that the common practice of directing penalty kicks to

the lower part of the goal (56.6% of the kicks reached this zone) is the least successful kicking strategy in penalty kicks. In contrast, the least used strategy of targeting the ball to the upper third of the goal produced more successful shots. They concluded that penalty takers should aim to the upper area of the goal, and in particular to the top two corners of the goal.

Performance Failure in Penalty Kicks

Interestingly, a study that examined the penalty kicks in the 1986 FIFA World Cup observed that about 70% of the 42 kicks taken landed two metres either side of the centralised goalkeeper (Bar-Eli, and Friedman, 1988). In other words, most of the penalty kicks did not land in the presumed optimal place. More recently, Miller (1996) examined the penalty kicks taken during the 1994 World Cup finals and concluded that 59% of penalty kicks landed relatively centrally (within 6ft either side of the goalkeeper) and only 41% landing to an optimal zone defined as within 6ft inside each post.

Indeed, despite the relatively large target area, and the fact that players frequently hit smaller targets over much longer distances (e.g. passes to players within game situations) a surprisingly large number of penalty kicks are missed. Many studies have attempted to establish the success rate of penalty takers in major competitions worldwide and there is a general consensus that this lies between 75% and 86% for top male professionals (McGarry and Franks, 2000). Therefore despite the relative simplicity of this seemingly rudimentary aiming task, a large proportion of penalty kicks are missed. There are a few notable examples of performance failure from the world of football that may further emphasise this point. For example, three recent European Champions League finals were decided by penalty shootouts (i.e., FC Bayern München-Valencia CF in 2001, AC Milan–Juventus FC in 2003, and Liverpool FC–AC

Milan in 2005), with a relatively high percentage of kicks being missed: 4 out of 11 (36.36%) in 2001, 5 out of 10 (50%) in 2003, and 5 out of 10 (50%) in 2005, which means that a total of 14 out of 31 shots (45.16%) were missed in those three top games, including penalties shot during the games themselves.

Such performance failure has caught the attention of sport psychologists, who have explored many variables they may affect performance in this task. Jordet, Hartman, Visscher, and Lemmink (2007) explored whether such performance failure was attributable to stress, skill level, physical fatigue or chance. Data were collected on 41 penalty shootouts comprising of 409 penalty kicks from major international competitions. Results indicated that the importance of the kicks (indicative of stress) was negatively related to the outcome, whereas skill and fatigue had little or no relation to outcome. This influence of anxiety on penalty kicking performance may be unsurprising giving the vast amounts of money that separates success and failure, the huge spectator presence and television audience, and the relentless media coverage in today professional game.

Jordet and colleagues have also explored how anxiety affects the behaviours of penalty takers and what effect these behaviours have on subsequent shooting performance. Jordet and Hartman (2008) analysed all the penalty shootouts from the FIFA World Cups, the UEFA European Championships, and the UEFA Champions League ($n = 36$ shootouts, 359 kicks) in an effort to examine the relationships between shot valence, avoidance behaviour and performance. Shots where goals instantly lead to victory were classified as positive valence shots and shots where a miss instantly lead to loss were classified as negative valence shots. Avoidance behaviour was defined as looking away from the goalkeeper or taking the shot too quickly (not waiting prior to beginning the approach to the ball). The results showed that avoidance behaviours

occurred more when players were shooting to avoid defeat (negative valance shots) compared to when they were shooting to win (positive valance) and players with negative valence shots performed worse than those with positive shots. The authors concluded that avoidance behaviours and disruptions to temporal aspects of penalty shooting (i.e. reductions in the wait before the initiation of the run-up) may help explain why soccer players choke under the pressure of penalty shootouts.

In a further study, Jordet, Hartman and Sigmundstad (2009) attempted to further investigate the temporal links to performance failure in penalty shooting. Video analysis of 366 penalty kicks explored the effects of different time periods typical in penalty shooting (walking to the penalty spot, ball placement, back-up, signal waiting (referee whistle), signal response, and run-up duration) on subsequent performance. Results indicated that longer times to respond to the referee's whistle were related to more goals and shorter times were related to more misses. In conclusion the authors postulated that the primary explanation for this finding was that extreme levels of pressure, typical in penalty shootouts, cause performers to exhibit escapist behaviours where they strive to get the situation 'over and done with' as quickly as possible. Further studies have shown such an explanation may be the principle factor in performance disruption in individuals high in public status (Jordet, 2009a) and may even explain why certain nations (such as England) suffer more so than others in this task (Jordet, 2009b).

While such research is applauded, and undoubtedly sheds light on the effects of anxiety and certain behavioural aspects representative of performance failure in real shootouts, one criticism is that it is rather descriptive in nature. In explanation, while this research does show that anxiety affects the behaviour of footballers taking penalty kicks, it fails to uncover and explain *how* and *why* these changes in behaviour disrupt a player's performance. To ascertain such a mechanistic account of performance failure in

this task experimental research needs to be carried out that explores anxiety's effect on cognitive aspects of performance that are known to influence aiming behaviour. One such area concerns gaze control, eye movements and attention (Wilson, 2008).

An Introduction to Gaze, Attention and Visually Guided Movement

Gaze behaviour

Gaze control is defined as the process of directing the gaze (head and eye movements) to specific objects or events within a scene in real time and in the service of the ongoing perceptual, cognitive and behavioural activity (Henderson, 2003). As a performer looks at a scene their gaze will fluctuate between periods of stability, where gaze is fixated, and periods of rapid movement between objects and locations. A fixation is defined when gaze is stable on an object or location within 3 degrees of visual angle for a period equal to, or longer than 100 ms (Vickers, 2007). This duration is thought to be the minimum amount of time that is needed to recognise and extract information from stimuli in the environment.

We move our eyes about three times each second via rapid eye movements (saccades) to reorient the fovea through the scene (Henderson, 2003). Saccades are the gaze behaviour that moves the eyes from one location to another within the visual scene. While saccades play no role in the extraction of visual information - all visual information is suppressed during saccades – they play an important role in moving gaze to locations of perceived importance so that such information can be foveated with maximal acuity for optimal informational extrication (Vickers, 2007).

Visual Attention

Visual attention is the cognitive process of selectively concentrating on one object or location in the environment while ignoring other irrelevant aspects. One model

of attention suggests that how an object or location is processed in everyday life is controlled via two segregated neural systems (Corbetta and Schulman, 2002). The top down goal-directed attentional system (influenced by current goals, expectations and knowledge) is centred on the dorsal posterior parietal and frontal cortex and is involved in preparing and applying goal-directed selection of stimuli and action responses. In this way attention is proactive in nature and guided by the current goals of the task. The stimulus-driven control system includes the temporoparietal cortex and inferior frontal cortex and is largely lateralized to the right hemisphere (Corbetta and Schulman, 2002). Corbetta and Schulman suggest that this ventral frontoparietal network works as a "circuit breaker" (2000, pp.201) for the dorsal system. This circuit breaking effect can be an adaptive process, directing attention to potentially important or salient events. When such events occur, the current attentional set is broken and a new one is adopted on the basis of the incoming stimulus. In this way top-down-attentional control can become stimulus driven and reactive in nature.

The relationship between gaze and attentional control

One important theoretical consideration of all gaze-based research is the question of whether measuring where a person is looking is actually where their attention is being directed. Early research that explored this important question has focused on the association between the direction of gaze and overt and covert attention. During overt attentional processes, both the direction of gaze and location of attention are associated. For example, a footballer player will look towards and concentrate on the location to which he wishes to shoot. During covert attention, gaze and attention are dissociated and a player may look to one side of the goal while striving to hit to the other side of the goal.

The results of these early studies indicated that it was easy to dissociate the direction of gaze from the direction of attention and therefore it was concluded that the external measurement of eye movements was inappropriate in measuring the internal process of attention (Posner, 1980; Treisman and Gormican 1988). However, such conclusions were based on findings using tasks that required a participant to focus centrally while detecting and attending to stimuli in the peripheral vision, thereby disassociating gaze and attention (Klein, 1979; Posner, 1980; Treisman and Gormican 1988). Whilst participants in these studies were able to attend to certain stimuli via peripheral vision without corresponding shifts in gaze, the problem with such conclusions is that they do not transcend to the visual behaviour seen in natural environments (Land, 2009).

In laboratory studies eye movements are treated as responses to stimuli, whereas most eye movements in the real world are proactive in nature, not reactive (Land and Furneaux, 1997). In such environments, participants find it difficult to make eye movements to one location and attend to another one (Shinoda, Hayhoe, and Shrivastava, 2001), even when participants know the destinations of attention and saccades well ahead of time, providing ample time to resolve any conflicts in programming (Hoffman and Subramaniam, 1995). Studies have also shown that allocation of attention affects saccade trajectories (Sheliga, Riggio, and Rizzolatti, 1995; Van der Stigchel and Theeuwes, 2007), have demonstrated a coupling between saccade preparation and spatial attention (Deubel and Schneider, 1996; Hoffman and Subramaniam, 1995; Kowler, Anderson, Dosher, and Blaser, 1995; Shepherd, Findlay, and Hockey, 1986), and have shown that the ability to make eye movements can affect covert attention (Craighero, Nascimben, and Fadiga, 2004; Smith, Rorden, and Jackson, 2004).

In fact, in natural environments attentional shifts precede saccadic eye movements, are associated with their preparation, and involve some of the same neuronal 'machinery' (Land and Furneaux, 1997; Land, Mennie, Rusted, 1999; Land, 2009); as supported by a number of psychophysical and imaging studies. Corbetta (1998) and Culham, Brandt, Cavanagh, Kanwisher, Dale, and Tootell. (1998) have demonstrated that the regions in posterior parietal and frontal cortex activated in fMRI studies of overt and covert attention are almost identical. Findlay and Gilchrist (1998) and Motter and Belky (1997) have also shown that attentional disruptions are reflected by fixations in visual search tasks. So eye movements do appear to reflect a shift of attention in natural environments... but how do the eyes guide action?

The Role of Gaze in Visually Guided Movement

Experimental studies have tested the critical dependence that accurate motor actions have on accurate eye movements. The focus of this research has predominantly concentrated on the effect that the disruption between eye and limb movements has on task performance. In the simple task of pointing to a target, pointing accuracy suffers when participants do not foveate to the target of the aiming movements (Bekkering, Adam, van den Aarssen, Kingma, and Whiting 1995; Neggers and Bekkering 1999; Vercher, Magenes, Prablanc, and Gauthier 1994) and when several visual targets are presented, eye and hand movements usually move to the same target (Gielen, van den Heuvel, and van Gisbergen, 1984). Neggers and Bekkering, (2000) also found saccades to new targets could not be made before the hand reaches the initial target location that was already fixated by the eyes. They termed this phenomenon 'gaze anchoring' and postulated that in order to guide coordinated motor actions, gaze remains on the target until the movement sequence is terminated. In a subsequent study, Neggers and Bekkering, (2001) reported that gaze was coordinated to the target of a pointing movement during the entire movement, even when visual information relating to the

pointing limb was occluded. Similar findings have been reported in more dynamic real-life motor tasks such as walking (e.g., Crowdy, Hollands, Ferguson, and Marple-Horvat 2000; Crowdy, Kaur-Mann, Cooper, Mansfield, Offord, and Marple-Horvat 2002) and driving (e.g., Chattington, Wilson, Ashford, Marple-Horvat, 2007; Marple-Horvat, Chattington, Anglesea, Ashford, Wilson, Keil, 2005; Wilson, Chattington, Marple-Horvat, and Smith, 2007). This research highlights the negative performance disruptions experienced when eye and limb coordination is compromised.

Whilst research on eye-limb coordination has been extensive, very little is known about how this coordination is developed during skill acquisition. In a recent study, Sailer, Flanagan and Johansson (2005) investigated how gaze behaviour and eye-hand coordination changed when participants learned a challenging and novel visuomotor task. In this task participants were required to move a cursor to a target display on a screen. Participants manipulated the cursor by applying isometric forces and torques to the tool held freely between the two hands. Results demonstrated changes in gaze behaviour and performance were observed over the learning period. Specifically, in the early stages of learning eye movements tended to follow the cursor, explicitly guiding it to the target location. When the skill had been mastered, cursor movement was not attended to, and eye movements tended to be target focused in nature, enhancing performance. Therefore individuals learn to program spatially congruent eye and motor commands, so that fixations on objects precede motor actions and provide visually acquired goal related information to the motor systems (Land, 2009; Neggers and Bekkering, 2000; Sailer, *et al*, 2005). Task-specific (goal-directed) eye movements of this nature support the planning and control of manual action and are therefore indicative of top-down attentional control and task expertise (Land, 2009).

A model for visually guided movements

Several distinct but interacting brain regions are responsible for the production and coordination of visually guided movements in natural environments. Indeed, Land (2009) suggests that three executive systems are responsible for gaze, vision and action, and these are overseen by a fourth system labelled the schema system. While this is not the only model, it has been developed to explain visually guided movement in natural environments so is relevant to sport.
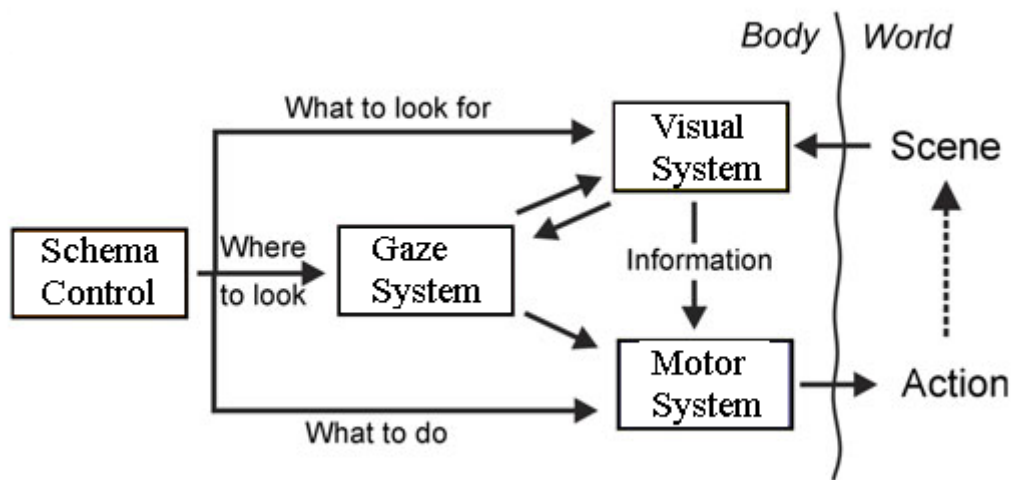
Figure 1. Relations of the schema, gaze, visual, and motor systems during the performance of a visually controlled action. Taken from Land (2009).

The gaze system (consisting of the frontal eye fields (FEFs) and the lateral intraparietal area of the parietal lobe) is responsible for locating and fixating (targeting) task-relevant objects. The visual system (located in the occipital lobe and much of the temporal lobe) supplies information to the other two systems, providing feedback as to what is being fixated and directional guidance to the motor system. In this way the eyes act like an 'advanced patrol', gathering the information necessary for successful performance (Land, 2009). In line with this it is generally accepted that eye movements tend to precede motor actions by about one second; although this is dependent on the specific task demands (Land and Furneaux, 1997; Land 2009).

The first visible response in visually guided action is usually an eye movement corresponding to the direction and location of some feature important for task execution. The eyes then fixate and extract the necessary information needed for the performance of the task. This information is then passed to the motor system via a memory buffer where it can be held for a short period of time before it is required to guide a motor response. The primary function of a memory buffer is to hold the information to allow a match between visual input and continuous motor output (Land and Furneaux, 1997). Such a facility can allow the eyes to look elsewhere, briefly, without interfering with the on-going motor action. The motor system (consisting of the primary motor cortex, the premotor cortex, and various parietal areas) controls the limbs and carries out task specific tasks.

These three systems are the subject of continuous management by the schema system, which is mainly located in the dorsal lateral prefrontal cortex (DLPFC; Land, 2009). This system represents an internal representation of the task that is used to guide action in a task-dependant, step-by-step fashion so that a coherent and timely action is produced. Land (2009) describes the schema as a basic unit of top-down control of action; "a set of instructions that determines where gaze will be directed, what information the visual system will be called upon to provide, and what action will be taken" (pp. 53-54). In essence this corresponds to the mechanisms that underpin top-down attentional control (Corbetta and Shulman, 2002) discussed previously.

One study that aptly shows how these systems may interact in natural environments was carried out by Land *et al*, (1999), and involved asking participants to make a cup of tea whilst wearing eye-tracking technology. Such a task was utilised has it involved many separate actions, and the transition of these actions could highlight how the schema system monitors and manages components of gaze, vision and action

for successful performance. Scan path analysis revealed that eye movements (saccades) were almost exclusively made in a systematic fashion, preceding motor movements, and reflected the step-by-step requirements of the task and the level of manipulation that each object (kettle, tap, mug, etc) required. In fact, a third of all fixations were linked to *locating* objects, *directing* the hand to a new location, *guiding* the approach of one object to another (e.g., kettle and lid), and *checking* the state of some variable (e.g., water level). The authors concluded that the eyes closely monitored every step of the process and suggested that this type of unconscious, top-down, attentional control attention must be a common phenomenon in everyday life (Land *et al*, 1999). It is evident from this body of research that in everyday environments, top down attentional control (even if unconscious), drives the eyes to lead and subsequent motor actions to follow.

This evidence has clear implications for performance in sport and in particular to sports requiring the coordination of eye and limb movements such as aiming. Collectively this research would suggest some fundamental recommendations for the production of accurate visuomotor control in sport. First, and in line with the work of Sailer *et al*. (2005), it is evident that expert performance can be reflected in the examination of gaze parameters. From a sport psychologist's perspective it must then be possible to examine what constitutes visual expertise and differentiates expert sport performers. Such an approach could not only uncover what environmental information is critical to masterful performance, but also be used to expedite the learning process for novices. Finally, in order to produce accurate motor responses, timely and target-congruent eye movements need to be initiated. Such coordination allows the eyes to provide the brain with important target-specific information that is critical in the production of accurate movement responses. The next section will now discuss how

parallel research in sport settings has also examined proficiency differences in gaze behaviours.

Visual Expertise in Sport

In order to exhibit expertise in sport, athletes must learn to search the visual display and pick out relevant task-specific information, whilst ignoring other irrelevant environmental stimuli that could interfere with task execution (Williams, Davids and Williams, 1999). Once the necessary information is located, the expert performer must focus their attention for an optimal duration to optimise the extraction of information critical for successful coordinated movement responses (Vickers, 2007). These aspects of visual expertise will now be discussed in relation to sport.

Cue utilisation and visual search

In a meta-analytic review, Mann, Williams, Ward and Janelle, (2007) attempted to quantify the differences in perceptual-cognitive skill between expert and non-expert sport performers. On analysis of 42 studies, results indicated three main findings relating to visual expertise in sport. First, experts are better at detecting and utilising perceptual cues. This is because experts possess extensive procedural and declarative knowledge that enables them to extract task-specific information that is utilised in predicting future events and in the preparation of responsive actions (French, Spurgeon, and Nevett, 1995; McPherson, 1999, 2000). Such expertise helps to reduce reaction time (Buckolz, Prapavessis, and Fairs, 1988; Helsen and Starkes, 1999) and increase the accuracy of the required response (Ericsson and Kintsch, 1995).

Second, experts display more effective and more efficient visual search behaviours with non-experts characterised by more fixations of shorter duration. This inefficiency is typical of non-experts searching the visual field for what they perceived to be the most important task-specific information needed for successful performance.

The consequence of this strategy is that more fixations of shorter duration are less efficient and are likely to be less effective than one involving fewer fixations of longer duration (Williams, Davids, Burwitz, and, 1993). This is because when under temporal constraints it is possible that incorrect, irrelevant information is processed or the necessary time needed to process and extract the information from task-relevant cues is unavailable. Indeed, as a performer produces eye movements to bring objects into the foveal field, the saccadic eye movements cause a decline in visual sensitivity and information processing. Theoretically due to the suppression of information process during saccades, a visual search strategy that uses fewer fixations of a longer duration is assumed to be more effective and efficient in the processing of task-relevant environmental stimuli (Willams, Davids, Burwitz, and Williams 1994). Proficiency (expert-novice) differences in visual search have been found in tasks including football (Helsen and Starkes, 1999), tennis (Singer, Cauragh, Chen and Steinberg, 1996), boxing (Ripoll, Kerlirzin, Stein and Reine, 1995), golf (Vickers, 1992), karate (Williams and Elliot, 1999) and squash (Abernethy, 1990).

The Quiet-Eye (QE) period

The final factor identified as a predictor of perceptual motor expertise in the Mann *et al*, (2007) study is the quiet-eye period (Vickers, 1996). The QE has been defined as the final fixation towards a relevant target prior to the execution of the critical phase of movement and has been accepted within the literature as a measure of optimal visual attentional control. Vickers (1996) suggests that the QE allows for a period of cognitive pre-programming of movement parameters (force, direction and velocity) while minimising distraction from other environmental or internal cues. This explanation may provide optimal attentional control and is also in theoretical alignment with Corbetta and Shulman's (2002) top-down, goal directed attentional system

discussed previously. This system is important for response or action selection and is involved in linking relevant stimuli to motor planning (Corbetta, Patel, and Shulman, 2008). Therefore the QE may help maintain effective goal-driven attentional control, while reducing the impact of the stimulus-driven attentional system.

In a seminal study, Vickers (1992) investigated the role of gaze control in golf putting. It was revealed that expert performers maintained a final fixation (QE) on the centre or back of the ball that was initiated prior to the execution of the initial movement of the putter head away from the ball and lasted for approximately 2000ms. In comparison, non-expert golfers displayed shorter final fixations (1000 -1500ms); a finding that has since been replicated by Vickers (2007) and Wilson and Pearcey (2009). These expert differences have been consistently reported in targeting tasks (Vickers, 1996; Janelle, Hillman, Apparies, Murray, Meii, Fallon, and Hatfield, 2000; Williams, Singer, and Frehlich, 2002; Vickers, 2004; Oudejans Koedijker, Bleijendaal, and Bakker 2005; Vickers and Williams, 2007), interceptive timing tasks (Adolphe, Vickers, and Laplante 1997; Vickers and Adolphe, 1997; Rodrigues, Vickers, and Williams, 2002; McPherson and Vickers, 2004; Panchuk and Vickers, 2006), and tactical tasks (Martell and Vickers, 2004; Vickers, 2007).

In sum, visual behaviours can differentiate between expert and non-expert sport performers and are subsequently imperative for performance success. Not only is it the case they eye movements should be target focused in nature; encapsulating the theoretical benefits of top-down attentional control, but it is also apparent that expert performers optimally utilise the visual system for the rapid detection of critical task-specific information and optimise the duration needed to process and respond for successful performance.

Vision and Action in Football Penalty Kicks

The goalkeeper's perspective

Early research that explored gaze behaviour during penalty kicks did so from the perspective of the goalkeeper using a visual search and cue utilisation paradigm. The consensus of this research has consistently shown that prior to shooting a penalty kick, goalkeepers tend to focus on the lower limbs of the kicker when extracting information to be used in anticipating shot direction (Dicks, Button, and Davids 2010; Savelsberg, Williams, van der Kamp, and Ward 2002; Savelsbergh, van der Kamp, Williams, and Ward, 2005). Further studies have also illustrated that a goalkeeper can manipulate their posture and location within the goal to promote inaccuracy in penalty kicks. Specifically, goalkeepers adopting a posture that mimics the Muller-Lyle illusion can affect the perception of their height and effect resultant shot accuracy (van der Kamp and Masters, 2008), and goalkeepers positioned off-centre within the goal can also manipulate shot direction (Masters, van der Kamp and Jackson, 2007). While there is obvious merit in using this information to train goalkeepers, in a penalty kick scenario the penalty taker is the favourite to succeed if a shot is struck to the optimal location on the goal (Bar-Eli and Azar, 2009) regardless of which anticipatory clue that the 'keeper is privy to. Despite this, a large number of kicks are missed and the gaze mechanisms behind this performance failure remain unclear.

The penalty taker's perspective

One of the first studies that made suggestions regarding the gaze behaviour of penalty takers was conducted by Kuhn (1988), who analysed 66 professional kicks from top-level German football. Kuhn observed two distinct kicking strategies, which he termed; 'keeper-dependent (KD) and 'keeper-independent (KI). The KD strategy involves the kicker focusing on the goalkeeper and waiting for his anticipatory

movements before shooting to the opposite side from which he dives. The KI strategy involves the kicker totally ignoring the goalkeeper, and instead preferring to focus where he is aiming.

While the KI strategy provides the best approximation of coordinated visuomotor control and aiming (Land, 2009; Neggers and Bekkering, 2001; Vickers, 2007), Kuhn suggested that approximately 70% of all shots utilise the KD strategy; not looking to where they intend to shoot. This centrally focused strategy obviously disrupts the optimal eye-limb coordination discussed previously, and seems somewhat counterproductive given that an accurately struck shot is almost impossible to save anyway. In a study that explored the temporal constraints of this strategy, van der Kamp (2006) explored the time-course over which penalty takers could change their direction of shot in relation to the movements of the goalkeeper. Results found that the decrease in the time available to alter kick direction resulted in a higher risk of inaccurate shooting. It is concluded that anticipating the goalkeeper's movements may degrade penalty kick performance, mainly due to insufficient time (<400ms) to modify the kicking action (van der Kamp, 2006). This evidence points to the fact that this strategy may be only effective if the goalkeeper dives early, however, should the goalkeeper remain stationary then the penalty taker must strive to hit an accurate shot using sub-optimal gaze information.

In order to be accurate in an aiming task it would be expected that a performer should look at the target area before making a movement, thereby optimising eye movements for visually guided action (Land *et al*, 1999; Land, 2009). The KI strategy would appear to maintain top-down attentional control by focusing on where the ball should be placed to beat the goalkeeper. Additionally, as research suggests that goalkeepers do not use the kicker's line of gaze to anticipate shot direction (Savelsbergh

et al, 2002; 2005), employing a target-focused strategy should not prime the goalkeeper as to the ensuing kick direction.

To date very few empirical studies have explored the gaze of penalty takers. Bakker, Oudejans, Binsch, and Van der Kamp (2006) investigated the effect of ironic instructions on penalty kicking performance. Wegner's (1994) theory of ironic processing purports that the instruction to avoid a thought or action may ironically increase the tendency to engage in this thought or action, especially when attentional resources are taxed. These researchers explored the effects of instructions that told performers to ignore the goalkeeper on subsequent shooting performance. Using a video-based penalty taking task their results suggested that such instructions facilitated performers to fixate on the goalkeeper when the time to take the shot was constrained. The authors also found that such a keeper dependent focus resulted in centralised shooting compared to when participants fixated to the space to either side of the goalkeeper.

In a similar video-based study, Binsch, Oudejans, Bakker, and Savelsbergh (2010) explored the impact of the same instructions on the duration of last fixation (QE: Vickers 1992) in penalty takers. Results indicated that ironic effects were accompanied by significant decreases in the duration of the last fixation on the target area and disrupted and centralised shooting. The authors postulated two explanations for this result: (1) the initial fixation on the keeper (induced by the ironic instructions to avoid him) lasted too long as to leave enough time for subsequent fixation of the open goal space, and (2) that the final fixation of the open goal space (after the initial fixation to the goalkeeper) was insufficient in duration due to gaze returning to the keeper. Similar findings were reported by Nagano, Kato and Fukuda (2006), who explored the optimal visual behaviour for accurate shooting in a simplified penalty kicking task. When

shooting using a single step approach to the ball (typical in five-a-side indoor football) it was found that accurate kicks were characterised by longer target-focused quiet-eye periods which occurred early in the preparation of the kick.

To conclude, from this research it is evident that disruptions to gaze behaviour in penalty kicks, whether induced by ironic instruction or a misguided reliance on a specific kicking strategy, is contrary to a vast body of research on the coordination of eye and limb movements (Land, 2009). Furthermore, expertise in shooting accuracy is predicted to occur if the correct target-specific information is focused upon, at the correct time for an optimal duration (QE). However a further consideration when exploring gaze behaviour in sport is the impact that anxiety has on eye movements, motor actions and subsequent performance. Indeed, even experts sometimes perform badly, or crumble under the pressure of competition. Why? What are the possible mechanisms behind such performance disruptions? The literature surrounding anxiety, gaze and performance disruption will now be discussed.

Anxiety and Gaze in Sport

Anxiety is typically considered as an emotion characterised by negative affect that impairs performance (Eysenck, 1996; Neiss, 1988). Several theorists have argued that the negative performance effects of anxiety are largely due to the manner in which worry and other forms of cognitive interference occupies or alters attention (e.g., Liebert and Morris, 1967; Sarason, 1988). It is this interference that is assumed to be responsible for anxiety-induced performance decrements or a phenomenon termed 'choking under pressure' in sport; acute performance decrements under circumstances of heightened incentive for good performance (Baumeister, 1984). Within this general conception a number of theories have been proposed to better explain the anxiety-

performance relationship in the hope to highlight how anxiety affects attentional processes using gaze as an objective (albeit proxy) measure of attentional control.

An early theory related to attentional control and anxiety was Easterbrook's cue utilisation theory, which considered the attentional narrowing effect caused by increased arousal. With a narrowing of the attentional field, it is proposed that performance on central tasks will be facilitated at the expense of peripheral tasks (Janelle, 2002). Janelle, Singer, and Williams (1999) found support for attention-narrowing effects that were due to heightened anxiety in an auto racing simulation. In this study drivers were required to navigate a racecourse while being required to identify the onset of relevant and irrelevant peripheral cues. When anxious, participants displayed a reduction in the capability to discriminate between relevant and irrelevant peripheral cues and performance was compromised. Additionally, these performance decrements were coupled with significant changes in gaze behaviour and attention. Specifically participants exhibited eccentric eye movements with more fixations made to peripheral locations. The authors concluded that such effects were typical of attentional narrowing as when participants were anxious the narrowing of peripheral vision meant that in order to discriminate between cues participants had to employ compensatory eye movements (Janelle, 2002).

Another theory that may explain anxiety's effect on attention and which has been tested in sporting environments is Wegner's (1994) theory of ironic processes of mental control. The pre-competition worry that athletes experience is almost exclusively related to performance outcome (Oudejans, Kooijman, and Bakker, 2010) and as such, anxious participants may ironically focus on aspects of performance that they know will result in poor performance. For example, a golfer may say "Don't hit this shot in the bunker" or "Don't over hit this putt". The theory of ironic processing purports that such

a thought may ironically increase the tendency to engage in this thought or action, especially when attentional resources are taxed such as when anxious. Such effects have been found in golf putting (Binsch, Oudejans, Bakker, and Savelsbergh, 2009; Wegner, Ansfield and Pilloff, 1998) and penalty taking, as previously discussed, and have been attributed to fundamental changes in gaze behaviour.

The most researched theory designed to explain the relationship between anxiety, attention and performance in sport is the Processing Efficiency Theory (PET; Eysenck and Calvo, 1992). This theory predicts that, when anxious, individuals use up vital processing and storage capacity of working memory through worry. Consequently, attentional resources available to process task relevant information (processing efficiency) are diminished, which in turn (potentially) causes degradation to effective task performance. A further prediction of PET is that worry may facilitate increases in on-task effort, thereby compensating for reduced processing efficiency. Therefore, this theory has an important theoretical distinction between processing efficiency and performance effectiveness. Performance effectiveness refers to the quality of task performance, whereas processing efficiency refers to the relationship between performance effectiveness and the amount of effort or attentional resources invested in performance (Eysenck and Calvo, 1992; Wilson, 2008). According to PET, anxiety will generally impair processing efficiency more than performance effectiveness. Support for this theory has been strong in the sport psychology literature (Behan and Wilson, 2008; Murray and Janelle, 2003; Williams, Vickers, and Rodrigues, 2002; Wilson, Smith, Chattington, Ford, and Marple-Horvat, 2006; Wilson, Chattington, Marple-Horvat and Smith, 2007; Wilson, Smith and Holmes, 2007).

While PET suggests that anxiety impairs the processing efficiency of the central executive of working memory, it lacks precision and explanatory power regarding

which specific function(s) of the central executive are adversely affected (Eysenck, Derakshan, Santos, and Calvo, 2007). Specifically, the central executive is argued to carry out five specific functions: switching attention between tasks; planning subtasks to achieve a goal; selective attention and inhibition (i.e., focusing attention on relevant information and processes and inhibiting irrelevant ones); updating the contents of working memory; and coding representations in working memory for time and place of appearance (Eysenck *et al* 2007). PET does not specify which one of these is negatively affected when anxious. Other important theoretical limitations are that PET does not account for the effects of distraction on performance; where anxious individuals are more likely to suffer performance decrements when presented with distracting stimuli (e.g., Calvo and Eysenck, 1996; Eysenck, 1992) or the increased effect when the distracting stimuli is threat-related (e.g., Egloff and Hock, 2001; Eysenck and Byrne, 1992; Keogh and French, 2001; Mogg, Bradley, Dixon, Fisher, Twelftree, and McWilliams. 2000). In recognition of these limitations, Eysenck *et al* (2007) proposed Attentional Control Theory (ACT).

Attentional control theory

ACT builds on the strengths of processing efficiency theory and the important distinction between processing efficiency and performance effectiveness remains a central tenet. The most general assumption of ACT is that anxiety increases the allocation of attentional resources to the detection of threat related stimuli in anxious situations. The authors relate this impairment of attentional control to a disruption in the balance of the two attentional systems, discussed previously, and first outlined by Corbetta and Schulman (2002); a goal-directed and stimulus-driven attentional system. Generally, anxiety is associated with an increased influence of the stimulus-driven attentional system and a decreased influence of the goal-directed attentional system

(Eysenck *et al*., 2007), due to the impairment of the 'inhibition' and 'shifting' functions of the central executive (Miyake, Friedman, Emerson, Witzki, Howerter, and Wager, 2000).

The inhibition function is primarily concerned with negative attentional control that prevents a performer from directing attentional resources to task irrelevant stimuli. The shifting function is associated with positive attentional control that shifts attention to task related stimuli, to meet ongoing task demands. Therefore, when in an anxious or threatening situation attentional resources are allocated to detection of a specific threat and in the planning of aversive or defensive actions. In this way, attention is more likely to be diverted away from task-relevant stimuli (top down attentional control) to the more threatening, irrelevant stimuli (stimulus-driven attentional control). ACT predicts that this anxiety-induced *inattention* to task-specific information may be the catalyst for performance degradation in highly anxious conditions (Eysenck *et al*., 2007).

Studies from cognitive psychology that have attempted to test the predictions of ACT have generally compared trait differences in anxiety, and used process-pure tasks to provide direct tests of the effect of anxiety on the specific functions of the central executive (see Eysenck and Derakshan, in press for a review). For example, the antisaccade task requires participants to make eye-movements to the opposite direction of a presented cue; a relatively pure test of negative attentional control and inhibition functioning. Results of studies adopting this task have tended to find that anxious individuals make more inaccurate saccades to the cued target and are slower to fixate on the opposite location than non-anxious individuals; revealing impaired use of the inhibition function (Ansari and Derakshan, 2010; Derakshan, Ansari, Shoker, Hansard, and Eysenck, 2009).

While the specific hypotheses of ACT require relatively 'process pure' tasks in which the specific functions of the central executive are isolated, as described above, such tasks are not representative of real world environments such as sport. However, the theory does provide a broader framework for understanding how anxiety may impact on attentional control in more applied settings such as sport (Wilson, 2008). Specifically, the theory suggests that anxiety increases stimulus driven attention control (at the expense of goal-direction attentional control; Corbetta and Schulman, 2002) causing performers to demonstrate an attentional bias towards threat related stimuli and increasing their susceptibility to distraction.

Attentional control theory in sport

Two recent studies have attempted to test the predictions of ACT in sporting environments using eye-tracking technology to monitor the effect anxiety has on the attentional control of performers. Nieuwenhuys, Pijpers, Oudejans and Bakker (2008) explored the changes in gaze behaviour of novices while traversing across a climbing wall of increasing heights to manipulate anxiety. When anxious, participants took longer to complete the traverse and this performance disruption was underpinned by disruption in attentional control. Specifically, anxious participants made more fixations of longer duration to hand holds and other locations relevant to climbing, indicating the utilisation of additional attentional resources and decreased processing efficiency. Further evidence for a decrease in processing efficiency was highlighted in the significant decrease in search rate between low anxious and high anxious conditions. This decrease suggested that when anxious, participants needed more time to extract the information from handhold locations.

Another study, more specific to aiming, was carried out by Wilson, Vine and Wood (2009) who used the quiet eye period (QE, Vickers, 1996) as a goal-directed

measure of attentional control in basketball free-throw shooting. They found that, when anxious, goal directed attentional control was impaired (shorter QE durations) as attentional control became more stimulus-driven (more fixations of shorter duration around the target). They concluded that the increased influence of stimulus-driven control was indicative of impairment in the inhibition function, and found that this effect resulted in significant impairments in performance accuracy.

While both studies show some support for the predictions of ACT, it could be argued that neither study provides a stringent test of its predictions. First, Nieuwenhuys *et al.*'s study was primarily a test of PET, as the role of competing attentional systems was not considered; simply that gaze control was less efficient. Wilson, Vine and Wood (2009) discussed the reduction in QE as reflective of impaired top-down attentional control, however the authors were unable to make any predictions as to why gaze would be more scattered around the hoop when performers were anxious (i.e. what drove the increased stimulus-driven attentional control). In the cognitive psychology literature, external visible distractions of a threatening nature are frequently used to provide stronger tests of anxiety-induced attentional disruptions (see Weierich, Treat, and Hollingworth, 2008 for a review).

However what both studies do show is that disruptions in gaze and attention resulted in disruption in performance. While ACT suggests that performance should not always be disrupted (Eysenck *et al*, 2007), these findings may suggest something unique about how anxiety affects motor planning and performance in visually guided movements. In visually guided movement, Land (2009) suggests that the eyes and subsequent motor actions share an interdependence necessary for accurate movement responses and that the control system responsible for this (the action schema; discussed previously) is located in DLPFC. In conjunction to this, and in explanation of how

anxiety may affect movement responses, recent neuroimaging studies by Bishop and colleagues has revealed that anxiety is also associated with disruptions to the attentional planning regions of the DLPFC (see Bishop, 2007, 2008, 2009). In broad terms, taken together the findings from Land, Bishop and Eysenck and colleagues may indicate that the neural mechanisms responsible for the production of coherent and timely movement patterns are also the neural mechanism disrupted when anxious.

Penalty kicks are one of the most highly anxious situations in world sport and as such they provide an interesting test of anxiety's effect on attentional control and performance. Despite this, no empirical evidence exists that has explored the unconstrained gaze behaviour of football penalty takers or the attentional disruption that anxiety may induce in this task. Furthermore, a football penalty kick is a task where there *is* a threatening environmental stimulus – the goalkeeper (see Chapter 3 for a discussion on the nature of this threat). For this reason this task may provide the opportunity for a more stringent and comprehensive test of ACT's predictions in a sporting environment.

Aims, Scope and Theoretical contributions of the Thesis

The aim of this series of studies was to (1) explore the gaze behaviour behind successful penalty shooting, (2) to uncover how anxiety affects attentional control and performance in this task and (3) to test the efficacy of a visual training regime on penalty kick performance under pressure. In the penalty kick there are a number of variables that could possibly influence performance; such as goalkeeper movement, variations in the run-up prior to ball contact and the inter-relationship between these two variables (e.g., van der Kamp, 2006). For these reasons this series of studies will begin with tight experimental control, so that the underlying processes may be examined and potentially confounding variables limited. However as these studies progress, and more

is learned about the gaze and performance measures, control of the goalkeeper, run-up and other constraints will be relinquished and manipulated to construct a more representative penalty kick environment. Such a systematic approach may help to answer four fundamental research questions. First, what is top-down attentional control for football penalty takers? Second, does anxiety affect the top-down attentional control of penalty takers, and if so, how? Third, what can goalkeepers do to maximise this disruption and increase their chances of success? Forth, can penalty takers be trained to optimise their attentional control, and performance, so both are robust under pressure?

By answering these fundamental research questions it is hoped a number of key contributions will be made to theory and scientific knowledge in this area of research. Until now, the gaze behaviours that penalty takers adopt have not been empirically examined using eye tracking technology. This research will examine the strategies proposed via video observation (Kuhn, 1988) to explore if they are actually utilised by penalty takers; how often each strategy is used; and how effective each strategy is in producing accurate shooting. This basic understanding of visuomotor control in this task will then enable a comprehensive examination of how such attentional control may break down under pressure.

Anxiety's affect on attentional control will be examined using attentional control theory (Eysenck *et al*, 2007) as a theoretical framework. This program of research will provide the most stringent test of the theory's postulations in a sporting environment to date and may also highlight how anxiety disrupts attentional control in the task of penalty shooting. A further study will expand on these postulations be exploring the effect of a distracting goalkeeper and anxiety on shooting accuracy in this task. Goalkeepers frequently utilise such behaviours yet empirical justification of their effectiveness is at present unexplored.

By exploring the eye movements and aiming behaviour of penalty takers during penalty shooting it is hoped that the visuomotor control necessary for consistent, accurate shooting will be uncovered. In the final study this information will then be utilised in the formulation of a gaze-based training intervention that can be taught to football players, It is hoped that such training will make their shooting performance more accurate, more consistent and robust under pressure. Whilst similar training (Quiet-eye training) has been conducted in other aiming based tasks (e.g., Causer *et al*, 2011; Vine and Wilson, 2011) this is the first study to attempt to train football penalty takers. It will also be the first study, to replicate an ecologically valid penalty shootout, with both teams present, under normal competition rules (e.g., one shot per participant per team). It is hoped that such a manipulation can induce to degree of pressure normally experienced in this task; thereby highlighting how pressure may disrupt attentional control and/or performance in this task. Such a manipulation will also test the degree to which attentional training elicits robust gaze control and performance under pressure.

In conclusion, this chapter has attempted to set out the theoretical considerations concerning anxiety, attention and visually guided movement. By linking current theoretical knowledge concerning visuomotor control, the structure and organisation of attention and attentional processes, and the effect anxiety has on attention, it is hoped that a strong empirical grounding has been established upon which the research within this thesis can now draw and expand upon.

Chapter 2: Gaze Behaviour and Shooting Strategies in Football Penalty Kicks: Implications of a 'Keeper-dependent Approach

Introduction

Investigation of visually guided movement tasks has revealed that the pattern and duration of eye movements are temporally and spatially coordinated with subsequent limb movement (see Land, 2009). It has been demonstrated that the information gained from preceding eye movements is important in maintaining performance. For example, research by Vickers and colleagues has demonstrated that in far aiming tasks, fixating on the target for an optimal period prior to the initiation of movement (quiet eye; Vickers, 1996) provides important information regarding target location and the force needed for the production of the ensuing motor response (see Vickers, 2007 for a review). Other researchers (e.g., Savelsbergh and van der Kamp, 2000) have discussed the importance of considering this 'perception and action' perspective, where information evolves over time, and where action is continuously coupled to the perceptual information presented. The objective of these two experiments was therefore to examine the control of visually guided aiming within a perception-action framework, for a specific, sport-based motor skill; football penalty shooting.

Since its first introduction, the penalty kick has had an increasing influence in the outcome of high profile matches, particularly in the tie-break shootout scenario (Miller, 1996). In fact, analyses of the goals scored in the 2004 UEFA European Championships and 2006 FIFA World Cup, revealed that 25% and 33% were scored via the penalty spot, respectively (Armatas, Yiannakos, Papadopoulou, and Galazoulas, 2007; Yiannakos and Armatas, 2006). Despite this increased impact, little research has been conducted concerning the aiming strategies employed by penalty kickers. This seems surprising considering the importance of this skill and the huge financial rewards on offer for success.

One of the first examinations of penalty kicking strategies was conducted by Kuhn (1988), who analysed 66 professional kicks from top-level German football. Kuhn observed two distinct kicking strategies, which he termed; 'keeper-dependent (KD) and 'keeper-independent (KI). The KD strategy involves the kicker focusing on the goalkeeper and waiting for his anticipatory movements before shooting to the opposite side from which he dives. The KI strategy involves the kicker totally ignoring the goalkeeper, and instead preferring to focus where he is aiming. While the KI strategy provides the best approximation of coordinated visuo-motor control and aiming (see Vickers, 2007), Kuhn suggested that approximately 70% of all shots utilise the KD strategy.

Probably the main reason for using the KD strategy is that by waiting until the goalkeeper dives in one direction before shooting to the other, the degree of accuracy needed is less (i.e., it is no longer necessary to hit the optimal scoring zone just inside the post). However, this strategy relies on the 'keeper making these anticipatory movements early enough to give the penalty taker time to extract the necessary information required to formulate an accurate response and adjust his/her kicking action accordingly. Van der Kamp (2006) examined the temporal implications of shooting utilising a KD strategy and found that penalty takers found it difficult to modify their kicking action if a 'keeper waited until at least 400ms prior to ball contact.

It is evident therefore, that the KD strategy relies on aspects of the task that are not within the control of the taker, and may be manipulated by the 'keeper to create an advantage. Indeed, Jordet, Elferink-Gemser, Lemmink, and Visscher (2006) explored the perception of control in penalty taking in professional players, and found that players who felt a penalty shoot-out to be a 'lottery' and down to luck were more likely to miss than those who believed the outcome was in their own hands. A KD strategy

may therefore be counterproductive from a psychological preparation viewpoint, where a focus on 'controlling the controllables' is recommended (e.g., Hardy, Jones, and Gould, 1996). Rather than wait to see what the 'keeper is going to do, the KI strategy would appear to maintain control by focusing on where the ball should be placed to beat the goalkeeper.

Dohmen (2008) suggested that an accurately hit shot, hit with average speed, would leave insufficient time for a goalkeeper to react and make a save. This finding would suggest that a KI strategy might be superior, if a penalty taker is sufficiently skilled to achieve this level of accuracy. Additionally, as research suggests that goalkeepers do not use the kicker's line of gaze to anticipate shot direction (Dicks *et al.,* 2010), employing a target-focused strategy should not prime the goalkeeper as to the ensuing kick direction. To maximise the chance of hitting this optimal scoring area, the perception-action research previously discussed would suggest that performers should fixate on the target location prior to shooting, in order to guide aiming and execution; in short, to look where they intend to shoot.

Kuhn's categorisation of these two kicking strategies was formulated via video analysis of games, and as no indices of gaze were obtained, the aiming strategies had to be estimated. Despite this limitation, studies examining penalty kicking techniques have used Kuhn's definitions to test the potential benefits of each strategy (e.g., Morya, Ranvaud, and Pinheiro, 2003; Van der Kamp, 2006). To date, only Bakker *et al*. (2006) have examined the gaze behaviours of penalty takers. Participants were asked to kick a sponge ball to a projected goal under time constraints. While this study did not seek to examine Kuhn's categories, it was found that participants tended to look where they aimed; with centrally focused fixations inducing more central ball placements.

The use of eye-tracking technology to explicitly examine where kickers look prior to shooting penalty kicks may therefore verify Kuhn's categorisations, or reveal alternative strategies. Do central fixations impair aiming control and subsequent performance? What strategies do penalty takers adopt when a 'keeper is present? Specifically, the aims of the following experiments were; first to explore the effect that centrally constrained gaze has on resultant performance and aiming coordination in a penalty-kicking task. Second, to assess the effect that the presence of a goalkeeper has in this scenario when gaze is not manipulated. Third, to explore what aiming strategies are employed by kickers when taking penalty kicks: How frequently are these strategies used and how effective are they in promoting accurate shooting?

Experiment 1

The aim of this first experiment was to explore the implications of centrally focused fixations on the aiming coordination and shot accuracy in a penalty-kicking task without any temporal constraints placed upon the kicker (cf Bakker *et al*., 2006). This data then provides a baseline performance measure to be compared to the influence a goalkeeper exerts on the task. The perception-action framework would suggest that penalty takers who look centrally but try to hit the ball to a corner should be less accurate than those who look at the corner prior to shooting; they should hit more centrally.

Marple-Horvat *et al*. (2005), in a study examining simulated driving found such a disruption in performance when gaze was experimentally constrained to a central location. When not constrained, drivers tended to look at the tangent point of the corner before steering round it, as evidenced by high correlations between gaze and steering positions during the drive. When forced to fixate centrally, this usual coordination was broken down and drivers tended to steer more straight ahead, with more subsequent

crashes occurring. While it is recognised that the attentional demands on a driver are very different from those on a penalty taker, it is thought that the manipulation of centralised gaze may provide similar performance outcomes. Therefore, it is predicted that without a goalkeeper present, skilled footballers will look to the corners of the goal and will accurately hit these areas. When their gaze is constrained centrally, it is expected that shots will also tend to hit locations that are more central.

Methods

Participants

Ten male university footballers aged between 19-22 years ($M = 20.0$, $SD = 0.9$) volunteered to take part in the study. All reported normal vision, were right-footed, had experience of taking penalty kicks and had between 8 to 16 years experience of playing competitive football ($M = 12.0$, $SD = 2.4$). These participants were classed as near experts (see Harle and Vickers, 2001) and at the time of testing played at the same competitive level. Local ethics committee approval and informed consent were obtained before testing.

Apparatus and Task

A standard 5-a-side goal (1.2m x 3.6m) was marked on an adjacent wall. This goal was split into 12 vertical, 30cm zones. These marked zones were later utilised for estimates of performance (where the ball hit) and gaze (where the kickers last fixated upon the target). Kickers shot an indoor football of standard size and inflation from a distance of 5 metres away from the centre of the target. 5-a-side rules dictate that players are only permitted a one-step 'run-up' before kicking the ball, which creates a simplified environment to study aiming fixations. An externally positioned digital video camera (Canon, MDl01) was located one metre behind and three metres to the right of

the participants. This view allowed the penalty spot and the whole target area to be visible for subsequent analyses.

Participants were fitted with an Applied Science Laboratories (ASL; Bedford, MA) Mobile Eye gaze registration system. This lightweight system measures eye-line of gaze at 25Hz, with respect to eye and scene cameras, mounted on a pair of glasses. The system works by detecting two features, the centre of the pupil and corneal reflection (determined by the reflection of an infrared light source from the surface of the cornea), in a video image of the eye. The relative position of these features is used to compute visual gaze with respect to the optics. The system incorporates a recording device (a modified DVCR) worn in a pouch around the waist and a laptop (Dell inspiron6400) with 'Eyevision' recording software installed.

A circular cursor, representing 1° of visual angle with a 4.5mm lens, indicating the location of gaze in a video image of the scene (spatial accuracy of ± 0.5° visual angle; 0.1° precision) is viewed in real time on the laptop and recorded for offline analysis. We defined our tolerance less stringently, to 1° visual angle (the diameter of the gaze cursor) because of the relatively dynamic nature of task. The DVCR was linked to the laptop via a 10m fire wire cable, permitting near normal mobility for the participant. The first author and the laptop were located behind a screen to the left of the participant, to minimise distraction.

Measures

Shooting accuracy (Ball destination). Performance was indexed by the accuracy of the kick, measured with respect to where on the goal the ball hit. This location was given an (x,y) coordinate with reference to the goal area (see Figure 2), via frame-by-frame analysis of the eye-tracker video file using Quiet Eye Solutions software (www.QuietEyeSolutions.com). Accuracy was assessed using the 'x' coordinate only,

as there was little variation evident in the vertical displacement of kicks. For example, shots that hit directly in the centre of the goal were given the score of zero. Higher points were then awarded for shots that hit further from the target centre, up to a maximum of 180cm (inside of post). A scoring system of this nature is representative of penalty kicking, as shots that are hit further from the 'keeper's reach are more likely to be successful.

Last fixation location. The same scoring system and method was utilised for measuring coordinates of last fixation. A fixation was defined as three or more gaze points within the same location that lasted 120ms (Vickers, 1996). Therefore, the location of the last fixation on the target prior to foot-ball contact was given an 'x' coordinate and its duration (ms) calculated using Quiet Eye Solutions Software. The last fixation was selected as the most critical aiming fixation as previous research has suggested that this is the critical period when key distance and force parameters for the skill are processed (Vickers, 2007).

Procedure

Participants first took ten practice kicks without wearing the eye tracking equipment, to familiarise themselves with the task. The eye tracker was then fitted and calibrated for each participant using a numbered grid that was marked on a wipe-board within the testing environment. Participants then took 14 shots in two counterbalanced conditions and were told that they should try to kick as they would do in real a game situation. In condition 1, participants were asked to look directly where they intended the ball to hit the target and to try and hit a successful penalty. It was suggested that they should try to aim for the inside of each post as this was the optimal scoring area. Condition 2 required the participants to look directly at the centre of a black cross that was marked in the centre of the goal area. However, participants were still asked to try

to hit the areas they previously selected, just inside the post. Each of the 14 kicks in each counterbalanced condition was alternated from hitting to the left post to the right post.

Calibration checks were carried out before and after each condition, consisting of asking the participant to look at a specific location in their visual field. Calibration checks were also carried out if the participant felt the eye-tracker glasses moved or if the researcher noticed any abnormalities on the scene output displayed on the laptop. Such occasions were relatively rare (11 occasions) and the line of gaze was re-calibrated quickly using the 'quick calibration' function in the 'Eyevision' software environment before proceeding with the testing protocol.

Data Analysis

Regression coefficients were calculated for gaze and outcome data across both conditions and used as a measure of aiming coordination (i.e., the linkage between gaze and subsequent ball destination). The difference in the location and duration of the last fixation across conditions was assessed using paired sample t-tests. The horizontal coordinates of ball destinations were analysed using a fully repeated measures 2 x 2 (condition x side of goal) ANOVA, to explore if there were any side preferences for left or right shots. The variance in shot accuracy (assessed by mean standard deviations) was calculated across conditions and analysed using paired sample t-tests. Effect sizes (ω^2) were calculated as outlined in Howell (2002).

Results

Aiming Coordination

In condition 1, where participants looked at the target area (inside the post), it was found that horizontal component of final fixation could successfully predict

eventual shot location ($R^2= 0.62$, $p <.01$; Figure 2). This indicated that participants looked where they wanted to hit and hit where they were aiming for. The lack of the same effect in condition 2 ($R^2= 0.13$, $p =.306$) reflects the different instructional set and demonstrates that the participants adhered to the instructions. The participants were prevented from looking towards their intended target area and therefore the coordination between final fixation and shot location was successfully broken down (Figure 2).
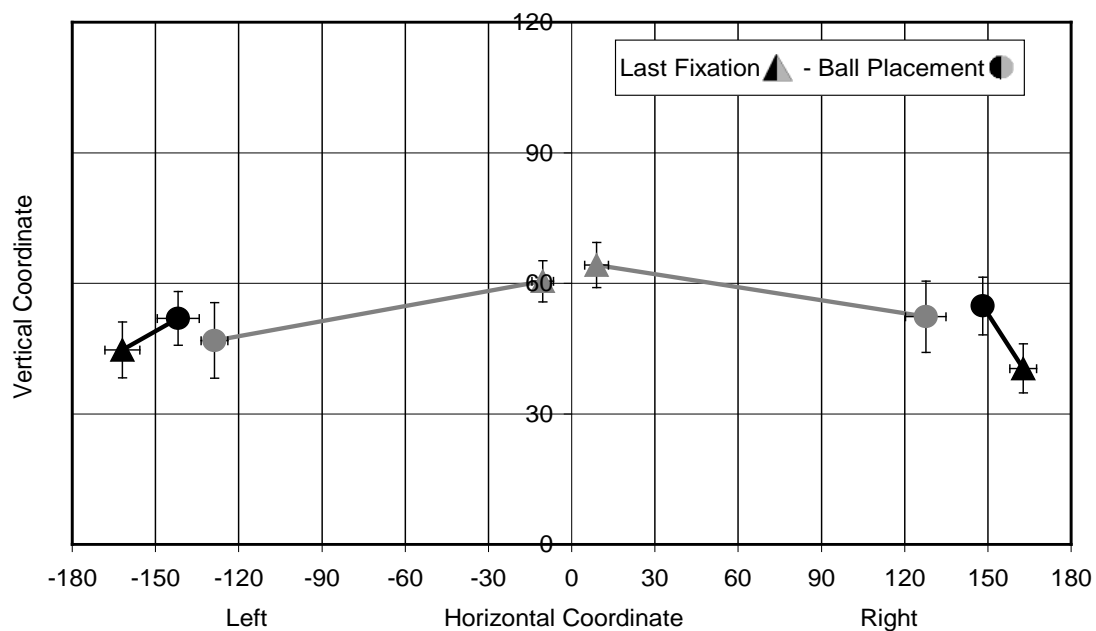
Figure 2. A representation of the target goal area, showing the mean (and s.e.m.) location of last fixation and mean (and s.e.m.) shot placements for left and right shots across conditions 1 (unconstrained gaze: black) and 2 (centrally constrained gaze: grey).

Gaze Behaviour

A significant difference was found between the location of last fixation, $t(9) = 34.46$, $p < .001$, $\omega^2 = 25.75$ between condition 1 and condition 2 (see Figure 2). Unsurprisingly, given that the instructions explicitly manipulated gaze, last fixations were significantly more centrally oriented in condition 2. A significant difference, $t(9) = 3.24$, $p < .05$ $\omega^2 = .80$, was also found between the duration of last fixation between condition 1 (mean of 280.65 ms, $SD = 96.49$) and condition 2 (mean of 422.94 ms, $SD =$

178.41). When participants were asked to look centrally and hit distal locations, their last fixation was significantly longer.

Performance

ANOVA revealed a significant main effect for condition, $F(1, 9) = 16.03$, $p < .01$, $\omega^2 = .70$, indicating that when participants looked straight ahead they hit significantly closer to the centre of the goal (mean distance of 127cm, $SD = 10.48$) compared to when they looked where they intended to aim (mean distance of 144cm, $SD = 12.72$). No significant main effect for side was found, $F(1, 9) = 0.09$, $p = .76$, showing that no systematic bias occurred due to kickers favouring the left (mean distance, 136cm, $SD = 19.65$) or right side (mean distance, 138cm, $SD = 16.25$). There was also no significant interaction effect, $F(1, 9) = 0.56$, $p = .47$. Centrally focused fixations resulted in kicks that were closer to the centre of the goal by a mean of 17 centimetres.

Further descriptive analysis of shots taken revealed that 19% (23/121) hit centrally (defined as 0 > 100cm) when kickers looked straight ahead, compared to only 4% (5/123 shots) when gaze was not constrained. Standard deviations for shot placements were 25cm and 34cm for conditions 1 and 2 respectively. A paired samples t-test analysis of these standard deviations revealed a significant difference, $t(9) = 3.43$, $p < .05$, $\omega^2 = 0.80$, between conditions. Not only did participants hit more centrally when constrained to fixate centrally, but they were also more varied in their performance.

Missed Shots

Of the 140 shots taken in each condition, 17 (12%) and 19 (13%) shots missed the target area (3.6 x 1.2m) in conditions 1 and 2 respectively. In condition 1 the linkage

between last fixation and ball placement was no longer evident for missed shots, $R^2 =$ 0.02, $p = .85$. The participants' mean last fixation for this condition was 177cm but their mean shot placement measured 207cm. For misses in condition 2, mean last fixation was measured at 9cm and shot placement at 208cm. Analysis revealed no significant difference, $t(16) = 0.05$, $p = .96$, between shot placement for missed shots between conditions.

Discussion

The coordination of gaze, aiming and action has been shown to be crucial for effective visuomotor performance (e.g., Land, 2009; Savelsbergh and van der Kamp, 2000; Vickers, 2007). In the current experiment, the disruption of aiming coordination brought about a significant reduction in kicking accuracy. Furthermore, when gaze was constrained centrally, not only were participants more likely to hit more centrally, but they had a greater spread of ball destinations compared to condition 1, when optimal coordination was maintained. However, the analysis of missed shots demonstrated that on occasions, even accurate and appropriate eye movements led to poor performance. There was no greater propensity to hit outside of the goal area in condition 2, when gaze was constrained centrally, compared to condition 1, when gaze was not constrained. This finding suggests that in these instances, errors in the movement output, beyond that influenced by eye movements, were the main reason for inaccuracy. Even the most skilful footballers can miss-kick and the fact that there are equally low numbers in each condition would suggest that such occurrences do not confound the conclusions drawn from the results.

Another interesting finding was that the duration of last fixation was significantly longer when participants were asked to focus centrally and shoot to distal locations. This difference is possibly due to participants utilising extra processing

resources and time to compensate for the disassociation of aiming coordination. Williams, Frehlich and Singer (2002) in a study examining billiards performance, also found that performers took longer and displayed longer final fixations for more difficult, as opposed to easier billiards shots. Despite this compensatory strategy, it was evident that participants were still more centrally constrained in their shot destination when gaze was constrained centrally (Figure 2).

In conclusion, this experiment aimed to determine the importance of making goal-directed fixations prior to motor output in a football penalty shot task. The results supported the findings of previous studies in other performance domains, in that eye and outcome measures were highly correlated when gaze was not constrained (e.g., Marple-Horvat *et al,* 2005; Wilson *et al.,* 2008). However, ball destination was constrained more centrally when gaze was directed more centrally, despite participants attempting to hit distal locations. Put simply, where the eyes looked shots tended to follow.

Experiment 2

Bakker, *et al*. (2006), have previously demonstrated that looking centrally promotes centralised shots when temporal constraints are placed upon the kicker. The results of experiment 1 illustrate further that even when temporal constraints on the kicker are lifted (self-paced), it is still difficult to accurately shoot to distal locations when gaze is constrained centrally. This finding would suggest that a KD approach to penalty taking (looking centrally) seems counterproductive and may result in a shot placed within easier reach of the 'keeper. The purpose of experiment 2 was therefore to provide a test of the use (and relative utility) of Kuhn's (1988) KI and KD kicking strategies, and to explore the effect that the presence of a goalkeeper has on aiming coordination and shooting accuracy.

First, all kicks were categorised as one of the strategies outlined by Kuhn, with similar ratios predicted (i.e., 70% KD; 30% KI). Next, the aiming coordination and performance scores were compared for each strategy. Based on the results from experiment 1 and the findings of Bakker *et al.*, (2006), it was hypothesised that those kicks shot using a KD strategy would be hit significantly closer to the centre of the goal. Conversely, it was expected that utilising a KI, target-focused strategy, would promote significantly higher performance scores.

Method

Participants

Twelve male university standard football players aged 18-22 years ($M = 20.3$, $SD = 1.2$) with competitive playing experience ranging from 8-16 years ($M = 12.2$, $SD = 2.2$) volunteered to participate in the study. The participants were classed as near experts, were all right-footed, reported normal vision and rated their penalty taking ability to be between five and eight out of ten ($M = 6.7$, $SD = 1.1$). Written consent was gained from all participants and local ethics committee approval was obtained before testing began.

Apparatus

The target area was exactly as in experiment 1, however, due to the incorporation of a goalkeeper, safety issues arose concerning him repeatedly diving on a hard floor surface. To counteract this, standard gym mats (32mm thickness) were used to cover the whole kicking area from one metre behind the penalty spot to right up against the wall and covering the full width of the goal. This allowed the goalkeeper to dive freely, in safety, while preventing the mats from affecting resultant ball destination. Participants were again fitted with an Applied Science Laboratories (ASL; Bedford, MA) Mobile Eye gaze registration system, as in experiment 1.

Measures

Similar performance, gaze and aiming coordination indices were recorded as in experiment 1.

Procedure

Participants attended individually and were told that the researchers were exploring gaze behaviour and penalty kicking performance. After taking 10 practice kicks at the target (without the goalkeeper) they were fitted with the eye tracker and calibration was performed using aspects of the goal (each corner of the goal, the centre and three points marked one metre above the goal). Participants were then instructed to take seven penalty kicks with the goalkeeper present. The eye-tracker calibration was then checked and they then took a further seven kicks. If errors were found in calibration it was quickly recalibrated as described in experiment 1. Participants were asked to try to score as many goals as possible, exactly as they would do in real match situations.

The goalkeeper was asked not to move before the penalty was struck but to try to save each penalty. He was located directly in the centre of the goal and stood knees bent with arms by his side and hands forward for each shot. His location and posture were standardised in this way as these variables have been shown to influence subsequent shot location in previous studies (Masters *et al.,* 2007; van der Kamp and Masters, 2008). The penalty takers were simply told that the 'keeper would try to save their penalties.

Data Analysis

On analysis of the video footage of the penalty kicks it became apparent that, as well as the KD and KI strategies, a previously undocumented strategy was evident. On

numerous occasions kickers adopted a strategy where they would look to one side of the goal whilst shooting to the other. From this point onwards, this strategy will be termed the opposite-independent strategy (OI). Kicking strategies were defined in terms of the relationship between the kicker's last fixation on the target prior to shooting, and resultant ball destination. A last fixation on the goalkeeper (who was within ±60cm of the central origin of the goal) coupled with a shot to any location was classified as the KD strategy. A last fixation on distal locations of the goal (> ±60cm to the left or right of the origin) coupled with a shot to the same side was classified as the KI strategy. If the last fixation was to one side of the goal (> ±60cm) and the ball was shot to the other, this was classified as the OI strategy. All kicks were thus subsequently divided into one of these three strategies.

From this data, percentages explaining the frequency of each strategy's usage were first calculated and compared. Three-way ANOVAs were carried out to explore the effect each strategy had on shooting accuracy and gaze behaviour. Effect sizes were presented as outlined by Howell (2002) and where sphericity was violated Greenhouse-Geisser correction was applied. Regression coefficients were then calculated to explore the effect that these strategies had on aiming coordination (location of last fixation and ball destination).

Finally, in order to provide some additional precision, beyond the grouped data level of analysis, inter and intra individual analyses were carried out for the best and worst shooter. The best shooter was the player who had the highest accuracy score (i.e. shot consistently further from the goalkeepers reach and closer to the post) and the worst shooter was the player who shot less accurately and closer to the goalkeeper. A series of independent t-tests explored if these individuals used different gaze strategies, defined in terms of the location of last fixation (in cm from centre of goal), the duration

of last fixation (in ms) prior to ball contact, and the number of preceding fixations used. Stepwise multiple regression analysis was carried out on the location of earlier fixations prior to shooting. This was designed to test our assumption that the last fixation was the most important for aiming and that other preceding fixations were unlikely to account for any difference in performance for the best and worst performer.

Results

Of the 168 kicks analysed, 22 (13%) were omitted due to technical failure or because the shot missed the target completely. The remaining 146 kicks were then divided into each kicking strategy. 52% (76/146) of penalty kicks were shot using the KD strategy, whereas the KI strategy accounted for only 22% (32/146) of the total kicks generated. Interestingly, the appearance of a third, and as yet, undocumented strategy was evident. This OI strategy was utilised for 26% of the kicks analysed in this study (38/146).

Group Data

A 3-way ANOVA revealed no significant difference in the shooting accuracy scores between kicking strategies, $F(2,62) = 1.14$, $p = .33$. However, as Table 1 demonstrates, the mean shooting accuracy scores for the KD strategy were lower than the KI and OI strategy. Indeed, it seems that utilising the KD strategy brought resultant shot placement inwards by 12 cm; a similar magnitude to that found in experiment 1. No significant differences were evident in the duration of last fixation between strategies, $F(1.36,42.15) = 17.91$, $p = .051$, however last fixation durations for KI kicks were shorter than for OI and KD kicks (see Table 1). There were no significant differences in the number of prior fixations used, $F(1.60,49.56) = 0.83$, $p = .42$ (see Table 1). Linear regression revealed that location of last fixation was ineffective in

predicting resultant ball destination for the KD ($R^2 = 0.04$, $p = .11$), the KI ($R^2 = 0.06$, $p = .17$) and OI ($R^2 = 0.00$, $p = .90$) strategy.

Individual Data

Figure 3 presents the kicking strategy usage for each participant and demonstrates that this was highly variable; both between and within participants. Most kickers adopted a combination of kicking strategies. However, this individual analysis reveals that the best shooters (to the left of the Figure) are less reliant on the KD strategy, whereas the poorer performers (to the right of the Figure) seem to rely heavily on the KD strategy. Indeed the best shooter utilised the KI strategy on 50% (7/14) of kicks whereas the worst shooter relied on the KD strategy for 100% of his kicks.
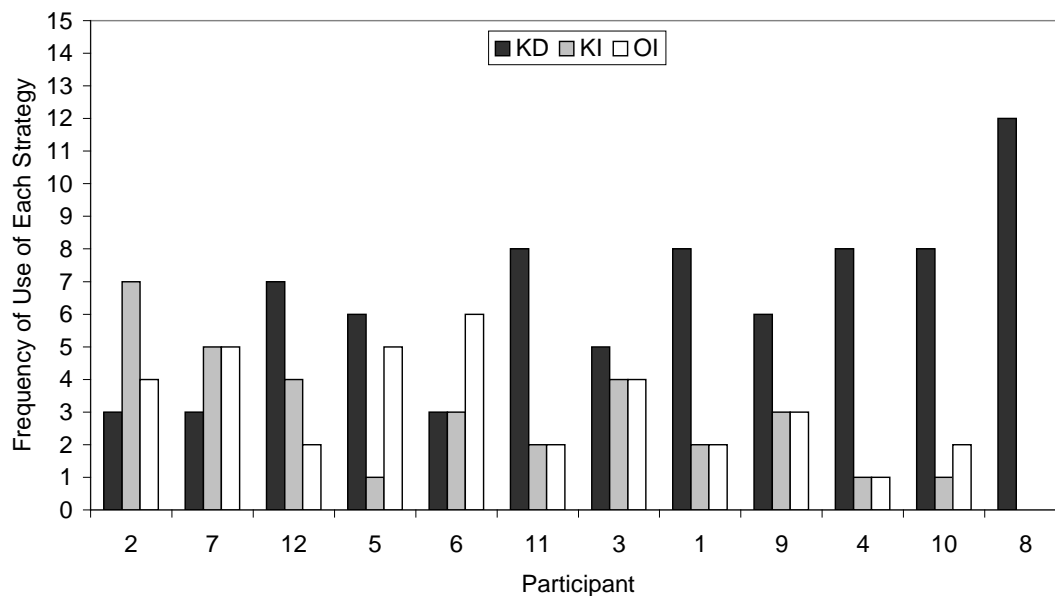
Figure 3. The number of penalties taken with each kicking strategy by each participant: KD ('keeper dependent), KI ('keeper independent) and OI (opposite independent). Participants are ranked from left to right in terms of decending performance (i.e. participant 2 was the best and participant 8 was the worst)

A more comprehensive examination of the gaze strategies of the best and worst performers revealed no significant difference between the number of fixations, $t(13) =$

0.49, $p = .64$, $\omega^2 = .12$ or last fixation duration, $t(11) = 1.83$, $p = .09$, $\omega^2 = .39$ prior to shooting (see Table 1). The only gaze behaviour that was significantly different between these participants was the location of last fixation, $t(12) = 9.93$, $p < .001$, $\omega^2 = 5.48$ with the worst performer fixating significantly more centrally. Regression analyses revealed that the location of last fixation could significantly predict ball placement in the best shooter, $R^2 = 0.38$, $\beta = .62$, $p < .05$[1]. However, last fixation was not a significant predictor of shot placement in the worst shooter, $R^2 = 0.04$, $\beta = 0.21$, $p = .51$. See Figure 4 for a schematic of the locations used by both the best and worst kicker across all their kicks.

Table 1. Mean (and standard deviations) for shooting accuracy and gaze behaviours for shots taken using one of the three kicking strategies, and for the best and worst performers.

	KD	KI	OI	Best Shooter	Worst Shooter
Performance (cm)	104.3 (39.2)	116.0 (38.1)	114.0 (38.0)	123.8** (19.4)	71.3 (38.3)
Location of Last Fixation (cm)	15.8** (18.8)	124.4 (28.6)	122.8 (40.3)	108.5** (34.2)	15.0 (17.1)
Number of Fixations	2.6 (1.4)	2.2 (1.0)	2.2 (1.1)	2.1 (0.9)	2.0 (1.2)
Duration of Last Fixation (ms)	328.8 (237.9)	223.3 (83.9)	316.8 (123.5)	220.0 (118.8)	275.7 (124.3)

KD = keeper dependent; KI = .keeper independent; OI = opposite independent. **$p < 0.001$

Due to the variability in the number of fixations made prior to shooting by the best and worst performer, multiple regression analysis was problematic. To compensate for this, we grouped the kicks of each performer based on the number of fixations they made prior to kicking. From Figure 4, it can be seen that the best performer made six kicks using two fixations. This provided a big enough sample to run the regression

analysis for the best shooter. This revealed that the location of last fixation was the only significantly predictor, $R^2 = 0.66$, β □= -.81, $p < .05$, of shot placement. A similar multiple regression was not carried out for the worst performer as, due to the higher variability in prior fixations, only 5 kicks had a comparable number of fixations and this was too small to carry out the statistical procedure. Nevertheless, the importance of the location of last fixation in the best performer illustrates the importance of looking where you are aiming immediately before shooting in this task.
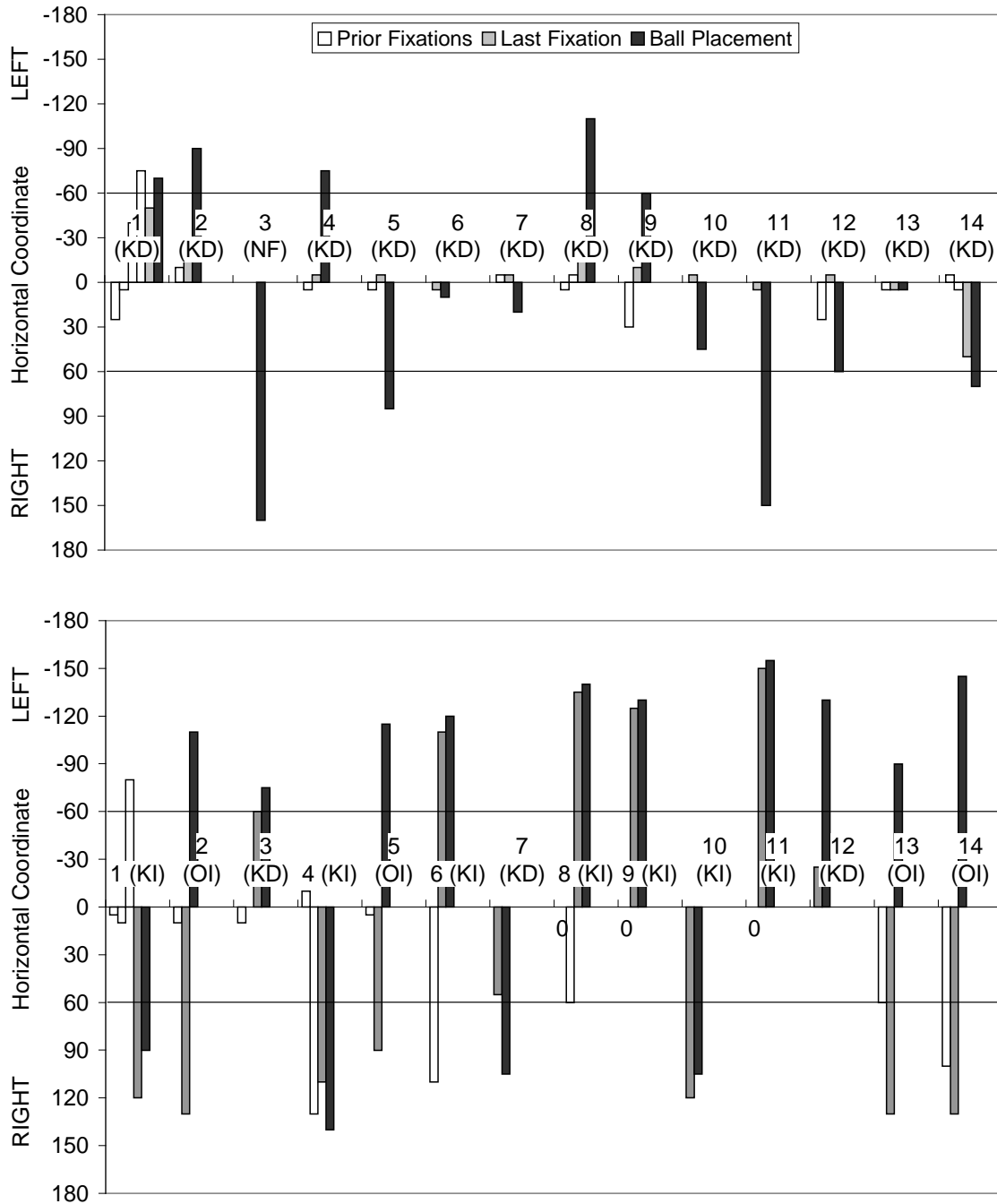
Figure 4. The location of all fixations made during the preparation for each kick (1-14) and subsequent ball placement, for the worst (top) and best (bottom) performer. The horizontal lines at ±60 cm reflect the area taken up by the goalkeeper and used to determine the KD strategy. Note that the 0's drawn on the bottom graph at kicks 8, 9 and 11 reflect a first fixation to the origin (0 cm). NF represents a kick with no prior fixations.

Discussion

This is the first experiment, as far as we know, to explore the varying kicking strategies employed by football penalty-takers using gaze registration technology. This approach allowed the previously determined kicking strategies to be verified using indices of gaze behaviour. While hypotheses were based on the results found in experiment 1, the impact of the 'keeper's presence on aiming coordination and shot strategy were somewhat exploratory. The major finding was that the KD and KI strategies were not the only ones employed by kickers. An OI strategy was identified where players seemed to try to deceive the 'keeper by looking one way and hitting another. While our results also suggest that the KD is the most prominent strategy utilised, the frequency of its implementation was lower than Kuhn (1988) found in his analysis of video footage of 11-a-side penalty shots.

The kicking accuracy results were also surprising, as although the KD strategy promoted inaccurate shooting, with shots typically landing closer to the 'keeper than for the KI strategy (by 12 cm), this difference was not significant at the group level. Furthermore, kicks taken with an OI strategy had similar accuracy as those where a KI strategy was adopted, despite the disruption between gaze and aiming intention inherent in this strategy. Contrary to the hypotheses, the grouped data also revealed that the location of last fixation in kicks taken using the KI strategy did not significantly predict resultant ball destination. These unexpected findings may reflect the lack of power of the small sample size, or, point to other factors beyond focal gaze location that affect aiming accuracy and coordination within this task. For example, the presence of the goalkeeper may have increased the perceived level of threat experienced compared to experiment 1. This might have contributed to the breakdown of the aiming coordination, as anxiety has been shown to affect gaze behaviour and subsequent performance in a number of studies (see Wilson, 2008 for a review).

While the grouped data provided only limited support for our predictions, the individual data (Figure 3) suggest that the worst performers predominantly used a KD strategy, whereas the better performers were more varied in their strategy use. The subsequent analyses performed on the gaze strategies of the best and worst performer provide a more detailed picture of the potential consequences of adopting a KD strategy (Figure 4). First, it is apparent that the worst performer relied exclusively on the KD kicking strategy, whereas the best performer predominantly used a KI approach. This is supportive of a coordinated gaze and aiming strategy being optimal, and a centralised keeper-based strategy being sub-optimal. The individual regression data support this postulation, as the location of last fixation significantly predicted ball destination for the best shooter, but did not for the worst shooter.

There were no significant differences in other potentially important gaze measures between the best and worst performer. These findings suggest that it is the location of the last fixation, rather than its duration, or the location of any earlier fixations which are important for successful aiming in this task. This is not to say that earlier fixations do not play some part in developing the kicking strategy. Interestingly, while the best performer predominantly employed the KI strategy he did not totally ignore the goalkeeper. In fact, on ten of his 14 shots (71%), the kicker's first fixation was located on the goalkeeper prior to choosing a distal, target location (Figure 4). Recent research has shown that looking at the goalkeeper may provide a penalty taker with information regarding his/her location and posture that may be used in the formulation of a successful shot (Masters, van der Kamp, and Jackson, 2007; van der Kamp and Masters, 2008). The best performer may be utilising this information in the decision making process involved in choosing a subsequent, appropriate shooting location.

In conclusion, it is apparent that there were three distinct aiming strategies employed by football penalty-takers in this experiment. The most popular of these was a centrally focused fixation on the goalkeeper prior to shooting. This strategy was indicative of inaccurate shooting at the individual level, yet it was still employed for around half of the shots taken at group level. The results of this experiment show that better performers align gaze behaviour with aiming intention when taking penalty kicks. This strategy likely provides the performer with the necessary visual information required for the generation of an appropriate and accurate response.

General Discussion

The purpose of these two experiments was to examine the role of gaze behaviour in aiming and executing accurate penalty kicks. The results of experiment 1 demonstrated the importance of coordinating gaze and aiming intention to maximise the chances of a successful outcome. This experiment highlighted that without the presence of a goalkeeper all participants looked where they were aiming, when not constrained experimentally. The results of experiment 2 illustrated that kickers utilise one of three kicking strategies when taking penalty kicks with a goalkeeper present. Unlike when the goalkeeper was not present, the most prominent kicking strategy in experiment 2 was the KD, centrally focused approach. However, reliance on such a strategy was shown to affect shooting accuracy in this task for the best and worst performers. Results of both experiments show some support for the notion that when looking centrally, shots were hit more centrally.

Despite the potentially negative implications of a KD strategy on performance, it was still the most prominent strategy utilised. If the disruption of gaze and aiming intention is detrimental to performance, as suggested, then why do kickers continue to utilise this focus? In game situations, this strategy may be useful if the 'keeper makes an

early decision to dive one way, leaving the other side of the goal unprotected (van der Kamp, 2006). However, the 'keeper did not move prior to ball contact in this experimental setting in order to maintain a degree of internal control over his influence. A second possible explanation is that the kickers are attempting to utilise the goalkeeper's position as a visual pivot, basing resultant aiming judgements on information gathered from peripheral vision.

While visual pivots have been shown to be important for kicking accuracy (Nagano *et al.,* 2006) it is thought that a visual pivot that is constrained centrally on the 'keeper is less effective than a pivot that is coordinated with aiming intention (looking where you intend to hit). This strategy would appear to be more effective as it would enable the goalkeeper to be monitored via peripheral vision, which is better than foveal vision at detecting movement. Williams and Elliott (1999) examining a karate defence task, found that better performers used a visual pivot strategy, consisting of directing foveal vision to the head or top of the chest and using peripheral vision to detect hand or foot attacks. More research is warranted in determining the role of foveal and parafoveal vision in coordinating gaze and aiming intention in penalty kicks, especially those using the KD or OI strategies.

The adoption of a combination of kicking strategies throughout the fourteen kicks by all but one of the participants was somewhat surprising. It was assumed that participants may be dependent on one particular strategy and this would be reasonably robust over time. Anecdotally, this seemed to be a reasonable assumption, as elite goalkeepers have been reported to study penalty takers before important matches to learn their preferences. However, our research design may have impacted upon this decision to vary strategies, as participants took 14 consecutive penalties, rather than the sole attempt possible in a penalty shoot-out. Attempts to maintain some degree of

deception and to prevent the goalkeeper from learning preferred techniques or scoring locations are likely to have facilitated this variability. Interestingly, the kicker who displayed the least variable kicking strategy was the worst performing kicker (Figure 3). However, as performance was actually assessed by 'ball destination' and not goals scored, it is likely his continued use of central fixations which impaired his performance, as opposed to his inability to deceive the goalkeeper, or anticipate his movements.

Despite the limitations of adopting a simplified environment and task, it appears that looking where you intend to aim is indicative of accurate penalty shooting. Additionally, and perhaps more importantly, it appears that looking centrally makes it difficult to accurately hit the optimal, distal target areas just inside the post. If the goalkeeper does not anticipate too early, leaving the other half of the goal empty, a centrally-focused strategy is likely to lead to more saved penalties. However, in the current study, kickers chose, either consciously or unconsciously, to employ such a sub-optimal aiming strategy when the goalkeeper was present, even when the goalkeeper did not attempt to anticipate kicking direction. Therefore, research into training strategies specifically designed to promote a KI approach is an avenue for possible further research. Of particular benefit would be interventions designed to manipulate gaze to target specific cues/locations imperative for accurate shooting. This has been shown to offer performance benefits in penalty taking (Wood and Wilson, 2008) and in basketball free throw shooting (Harle and Vickers, 2001).

In conclusion, research findings consistently show that by looking where you are aiming, shooting accuracy is at its optimum; in this study we found some support for this prediction. However, penalty takers frequently utilise a centrally focused (KD) strategy while still trying to shoot to distal locations. By adopting this strategy they risk

shooting closer to the goalkeeper, making a save more likely. More research is required to understand how penalty takers decide upon their strategy and how each strategy can be optimised for a given situation. From a more general perspective, studies like the current one, which adopt a perceptual-action framework (Savelsbergh and van der Kamp, 2000) may help further our understanding of how the perceptual and motor systems combine to optimise performance in a variety of aiming tasks.

Chapter 3: Anxiety, Attentional Control and Performance Impairment in Penalty Kicks

Introduction

The influence that anxiety exerts on sporting performance continues to be of major interest to sport psychologists. Various explanations for visuomotor performance impairments caused by increased anxiety have been linked to the disruption of attentional control (see Janelle, 2002, and Wilson, 2008, for reviews). A recent theoretical development from cognitive psychology, Attentional Control Theory (Eysenck *et al*, 2007), may therefore provide a useful framework by which to understand such performance disruptions.

ACT is an extension of processing efficiency theory (PET; Eysenck and Calvo, 1992), which has previously received support in the sport anxiety literature (e.g., Behan and Wilson, 2008; Murray and Janelle, 2003, 2007; Nieuwenhuys *et al.,* 2008; Williams and Elliott, 1999; Williams, Vickers, and Rodrigues, 2002; Wilson, Smith, and Holmes, 2007; Wilson, Chattington, Marple-Horvat, and Smith, 2007b; Wilson, Smith, Chattington, Ford, and Marple-Horvat, 2006). Whereas PET makes predictions about the effect of anxiety on the general efficiency by which information is processed, ACT is more explicit about the specific attentional processes involved. In this way, the theory shares similarities with other theoretical models of anxiety disorders that propose that anxious individuals both orient more rapidly to anxiety-inducing stimuli, and disengage from them more slowly (see Weierich *et al*., 2008, for a review).

The most general assumption of ACT is that worry increases the allocation of attentional resources to the detection of threat-related stimuli in anxiety-inducing situations (Eysenck *et al*., 2007). The authors attribute this impairment of attentional control to a disruption in the balance of two attentional systems: a goal-directed (top–down) and a stimulus–driven (bottom-up) attentional system (Corbetta and Shulman, 2002). Whereas the goal-directed system is influenced by current goals and

expectations, the stimulus-driven attentional system responds to salient or conspicuous stimuli. According to ACT, anxiety impairs processing efficiency by reducing attentional control and making it difficult for the goal-directed attentional system to override the stimulus-driven attentional system, especially in the presence of threat-related distracting stimuli (Eysenck *et al.,* 2007).

A recent study by Wilson, Vine, and Wood (2009) tested the predictions of ACT in a sport setting using a basketball free throw task. The authors used the quiet eye period (Vickers, 1996) as a goal-directed measure of attentional control and found that quiet eye durations were significantly reduced in a high-threat condition. Similar to previous studies that have investigated the effects of anxiety on the quiet eye period in far aiming tasks (Behan and Wilson, 2008; Vickers and Williams, 2007), this reduction in goal-directed attentional control led to a significant drop in performance effectiveness (reduced free throw percentage accuracy).

Football (soccer) penalty shooting is another example of a visuomotor far aiming skill in which pressure can influence performance. Indeed, anxiety has been reported to be *the* major contributor to suboptimal performance in penalty kicks (Jordet, 2009a; Jordet, 2009b; Jordet *et al.,* 2006; Jordet *et al*, 2007). Jordet *et al*. (2006) explored professional players' perception of control in penalty taking and found that players who felt a penalty shoot-out to be a "lottery" were more likely to miss than those who believed the outcome was in their own hands. Clearly, the goalkeeper's actions are the principal source of uncertainty bearing on the shooter's success in achieving his or her goal, in what would otherwise be a straightforward aiming task. Uncertainty has been linked with heightened feelings of threat (Fisher and Zwart, 1982) and increases in cognitive anxiety (Lox, 1992). Given that the goalkeeper is therefore a threatening external stimulus in this evaluative situation, we were interested in

determining what effect the goalkeeper might have on the penalty taker's attentional control and performance.

In explaining how anxiety impacts upon attentional control, Eysenck *et al.* (2007) suggest that, "Threat to a current goal causes attention to be allocated to detecting its source and to deciding how to respond" (p. 338). In the case of penalty shooting, an anxious player may therefore be more likely to attend to the goalkeeper as a source of threat, and attempt to anticipate the goalkeeper's movements. Previous research investigating football penalty performance in experimental settings (e.g., Bakker *et al.*, 2006; Van der Kamp, 2006; Van der Kamp and Masters, 2008) has demonstrated that attending to the goalkeeper may be detrimental to performance, as shots are subsequently placed closer within the goalkeeper's reach. Therefore, it has been advised that penalty takers should ignore the actions of the goalkeeper and instead should adopt a top–down attentional strategy, focusing on target-specific locations: the corners of the goal area (Van der Kamp and Masters, 2008).

The influence of anxiety on the visual attention and subsequent performance of penalty takers is therefore of theoretical and practical interest to cognitive sport psychologists. The aim of this research was to discover what effect anxiety has on gaze behaviour in a penalty-kicking task and to assess these attentional changes within the theoretical context of attentional control theory (Eysenck *et al.*, 2007). Under ego-threatening conditions, ACT would predict that the goalkeeper—as a salient, conspicuous, and threatening stimulus—would draw the attention of the kicker to a greater extent than under nonthreatening conditions. Such a reduction in the efficiency of attentional control is likely to degrade far aiming performance (as in Wilson, Vine and Wood, 2009). Specifically, it was hypothesized that in the high-threat condition, footballers would fixate earlier (rapid orientation to threat) and for longer (disengage

slowly) on the goalkeeper before shooting. This more central, as opposed to distal (target-focused) gaze pattern should result in shots being hit to significantly more central locations (as in Bakker *et al.*, 2006).

Methods

Participants

Fourteen male university standard football players aged 18–22 (mean age, 20.4 years, $SD = 1.1$) with competitive playing experience ranging from 8 to 16 years (mean, 12.2, $SD = 2.0$) volunteered to take part in the study. All were right-footed, reported normal vision, and rated their penalty-taking ability to be between 5 and 8, out of 10 (mean rating of 6.5, $SD = 1.2$). Written consent was gained from all participants and local ethics committee approval was obtained before testing began.

Task Setup

A standard-sized indoor soccer ball was shot toward a goal that was marked out on an adjacent wall. This target measured 3.6 m × 1.2 m, which is in accordance with regulation indoor soccer goals (JP Lennard, Ltd.; Warwickshire, U.K.), and made up of twelve 30-cm vertical zones that were marked to aid the analysis of shot location. Shots were taken 5 m from the center of the target, again in accordance with standard indoor football rules. To reduce the potential for injury to the goalkeeper, standard gym mats (32 mm in thickness) were used to cover the entire kicking area from 1 m behind the penalty spot to right up against the wall and covering the full width of the goal. This allowed the goalkeeper to dive freely, in safety, while preventing the mats from affecting resultant ball destination.

The same goalkeeper was used throughout the testing period, and he was instructed to try to save each penalty, but not to move before the penalty was struck. He

stood directly in the centre of the goal with knees bent, arms by his side and hands in front of his body before each shot (see Figure 5). His location and posture were standardized in this way because these variables have been shown to affect performance in penalty taking (Masters, van der Kamp, and Jackson, 2007; Van der Kamp and Masters, 2008). These instructions sought to ensure that participants did not attempt to anticipate the goalkeeper's movements, but instead select their own goal-directed target locations. The penalty takers were simply told that the goalkeeper would try and save their penalties and that they should try and shoot to the areas of the goal where they would have the best chance of scoring.

Figure 5. A screen grab from the GazeTracker software environment showing the experimental setup and the two "LookZones" (areas of interest): the goalkeeper (A) and the goal area (B). The circular cursor, to the goalkeeper's left, represents the participant's point of gaze.

Apparatus

Participants were fitted with an Applied Science Laboratories Mobile Eye gaze registration system (See Chapter 1). The researchers and the laptop were located behind

and to the left of the participant, to minimize distraction. An externally positioned digital video camera (Canon; MD101) was located 2 m behind and 4 m to the right of the participants. This view allowed the penalty spot and the whole target area to be visible.

Design

Participants performed under low- and high-threat counterbalanced conditions, in a repeated measures research design. In the low-threat condition, non-evaluative instructions were provided to participants, asking them to do their best but stressing that the research was testing the reliability of the calibration of the eye tracker for football tasks. In the high-threat condition, several manipulations were used to attempt to ensure that high levels of pressure and ego threat were created (as in Behan and Wilson, 2008; Murray and Janelle, 2003). Participants were made aware of a £50 prize for the kicker with the highest accumulated score. In addition, they were told that a leader board with each participant's name and score would be circulated among all participants. Participants were also told that overall scores would be generated by a computer algorithm developed in a previous study, which analyzed various measures related to shot execution. They were informed that it would be impossible to gauge how well or badly they were doing throughout the trial, so it was best to focus on executing their penalties as they would do normally. This information was introduced to minimize potential reductions in effort and task motivation over successive trials.

Measures

State Anxiety. The Mental Readiness Form-3 (MRF-3; Krane, 1994) was used to measure state anxiety. This is a shorter alternative to the Competitive State Anxiety Inventory-2 (CSAI-2; Martens *et al.,* 1990) with correlations of 0.76 for cognitive anxiety, 0.69 for somatic anxiety, and 0.68 for self-confidence. The MRF-3 has three

bipolar 11-point Likert scales that are anchored between *worried* and *not worried* for cognitive anxiety, *tense* and *not tense* for somatic anxiety, and *confident* and *not confident* for self-confidence. This measure was selected as it is a short, expedient inventory that has been employed in other studies testing ACT in sporting environments (e.g., Wilson, Vine and Wood, 2009).

Performance. To minimize the influence of goalkeeper performance on results, a measure of target accuracy was adopted, rather than a measure reflecting goals scored. Target accuracy was measured depending on where on the goal the ball hit, with this location being given a horizontal (*x*) coordinate (in centimetres), relative to the center of the goal. Each half of the goal consisted of six zones of 30cm, starting from an "origin" in the centre and moving out to 180 cm at the post (see Figure 5). Higher scores (in centimeters from the central origin) therefore reflected shots that were placed further out of the goalkeeper's reach, where they would have greater chances of scoring (Van der Kamp, 2006).

The coordinate was determined via frame-by-frame analysis of the eye-tracker video file using Quiet Eye Solutions software (www.QuietEyeSolutions.com), with a precision of 5 cm (one-quarter the diameter of the ball). On 14 occasions, the goalkeeper made a save (8 in the no-threat and 6 in the high-threat conditions), in which case the ball did not strike the target area. On these occasions, an estimation of where the ball would have hit was made independently by the second and third authors. Interrater reliability scores were 99.3%

Time to First Fixation on the Goalkeeper. The time taken to orient a first fixation to the goalkeeper from the onset of the trial was measured in seconds using QuietEye Solutions software. This measure was designed to reflect early orientation toward threatening stimuli.

Mean Fixation Duration. The mean fixation durations (in milliseconds) to each target location (i.e., the goal area and the goalkeeper) in each trial were calculated in the GazeTracker software environment (see Data Analysis). This measure was designed to reflect attentional disengagement, that is, the extent to which attention was grabbed and maintained by each location.

Mean Number of Fixations. The mean number of fixations to each target location in each trial was calculated (see Data Analysis). Whereas longer mean fixation duration to an area may indicate delayed disengagement from targets, more fixations to one target location may indicate heightened distractibility to that target.

Preparation Time. The time taken to prepare the shot (trial duration) was calculated in seconds from the external video footage. Trial onset began on the instant the kicker took his hands away from the ball after placing it on the penalty spot and ended on foot-to-ball contact.

Procedure

Participants attended individually and, after giving their written consent, were told that the aim of the study was to compare kicking performance under different conditions. They familiarized themselves with the testing environment by taking 10 kicks at the target goal with no goalkeeper present. The goalkeeper was excluded at this stage to prevent any previous learning (side preferences, kicking style) occurring for both goalkeeper and kicker. After taking their familiarization kicks, the participants were then fitted with the eye tracker and this was calibrated using each corner of the goal, the center of the goal, and three other points that were marked 1m directly above each post and center of the goal. Further quick calibration checks were carried out if the participant felt the eye-tracker glasses had moved or if the researcher noticed any abnormalities on the scene output displayed on the laptop.

Participants were then provided with instructions related to the condition in which they were going to perform, and subsequently completed the MRF-3 before taking four of the seven penalty kicks for that condition. The manipulation instructions were then reiterated and the MRF-3 completed again before the final three kicks were taken. This procedure was adopted to allow a measure of self-reported anxiety to be recorded *during*, as opposed to just before each testing condition, and to reinforce the anxiety manipulation, which may be diluted over repeated trials (see also Wilson, Smith, *et al*., 2007).

Data Analysis

Point-of-gaze data (consisting of .avi and .csv files) from the Mobile Eye were analyzed using GazeTracker Software (Eye Response Technologies, VA). A "Look-Zone" (area of interest) was created around the goalkeeper and the goal area, and these were manipulated in a frame-by-frame fashion. This allowed the LookZones to remain stable around the area despite movement in the kicker's visual field (See Figure 5). The software then automatically measured the mean number of fixations and each fixation's duration within these pre-established LookZones. Summary statistics for each trial then enabled the mean number of fixations and their mean fixation duration to be calculated for each LookZone (see Measures). Inter-rater reliability of a sample of 140 kicks was 96.1%. A fixation was classified as three or more consecutive frames (≥ 120 ms) in which the cursor stayed in the same location (Vickers, 1996).

Statistics

MRF-scores, time to fixate on the goalkeeper, preparation time, and performance data were analyzed using paired sampled *t* tests to explore differences between the conditions. Mean fixation duration and the mean number of fixations were calculated for each condition and each fixated location of interest (i.e., goalkeeper and

goal area). These were then analyzed using a series of fully repeated measures 2×2 ANOVAs (Condition $\times$ Location). Significant effects were followed up with Bonferroni-corrected post hoc t tests. Effect sizes were calculated using partial eta squared (ηp^2) for omnibus comparisons and Cohen's d for pairwise comparisons (Cohen, 1988).

Results

Of the 196 shots taken in total, 29 (14.7%) were excluded owing to technical failure of the eye tracker (11 in the low-threat and 8 in the high-threat condition), or were deliberately excluded because shots missed the target area completely (4 in the low-threat and 6 in the high-threat condition). This left a sample of 167 kicks between low- (83 kicks) and high-threat (84 kicks) conditions.

State Anxiety

There was a significant difference, $t(13) = 5.1$, $p < .01$, $d = 1.11$, in the self-reported cognitive anxiety scores between the low-threat (mean rating of 2.8, $SD = 1.3$) and high-threat (mean rating of 4.6, $SD = 1.9$) condition. Participants reported significantly increased cognitive anxiety in the high-threat condition. Somatic anxiety was also significantly lower, $t(13) = 4.9$, $p < .01$, $d = 0.90$, in the low- (mean rating of 3.4, $SD = 1.4$) as opposed to high-threat condition (mean rating of 4.8, $SD = 1.7$). The reported level of self-confidence did not significantly differ across threat conditions, $t(13) = 1.9$, $p = .07$, $d = 0.54$. However, reported confidence scores were marginally higher (a moderate effect size) in the low- (mean rating of 8.0, $SD = 1.2$) compared with high-threat (mean rating of 7.3, $SD = 1.4$) condition.

Performance

There was a significant difference, $t(13) = 2.30$, $p < .05$, $d = 0.78$, in the performance accuracy between low-threat (mean distance of 117.21 cm, $SD = 13.99$), and high-threat (mean distance of 103.28 cm, $SD = 21.03$) conditions. Shots in the high-threat condition were placed significantly closer to the center of the goal (nearer the goalkeeper) than those in the low-threat condition.

Gaze Behaviour / Attentional Control

Mean Number of Fixations. A significant main effect was found for condition, $F(1, 13) = 8.95$, $p < .05$, $\eta p^2 = 0.41$, with participants making significantly more fixations in the high-threat ($M = 13.00$, $SD = 10.02$) as opposed to the low-threat condition ($M = 10.29$, $SD = 10.02$). No significant main effect was evident for location, $F(1, 13) = 3.60$, $p = .08$, $\eta p^2 = 0.22$, and the interaction effect was also found to be non-significant, $F(1, 13) = 1.57$, $p = .23$, $\eta p^2 = 0.11$. The mean number of fixations data are presented in Figure 6.
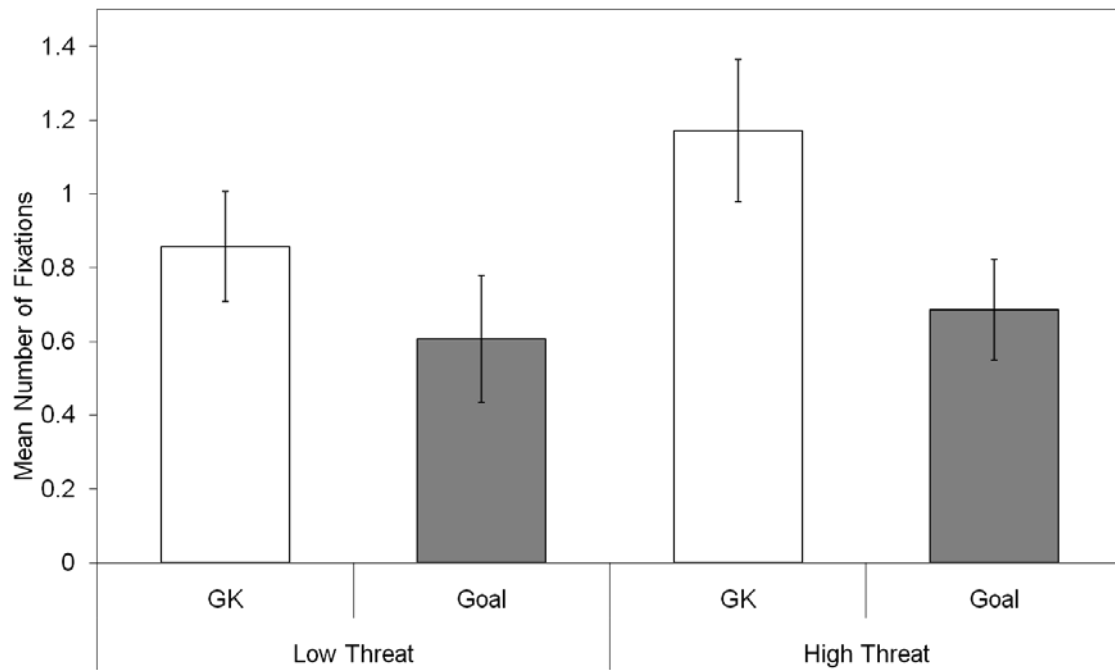
Figure 6. Gaze behaviour data, showing the mean number of fixations to each location under low- and high-threat conditions (with standard error of the mean).

Mean Fixation Duration. A significant main effect was found between conditions, $F(1, 13) = 6.88$, $p < .05$, $\eta p^2 = 0.35$, indicating that participants spent significantly longer periods of time fixating on both locations under the high-threat ($M = 0.43$ ms, $SD = 0.41$) compared with low-threat condition ($M = 0.34$ ms, $SD = 0.22$). There was a significant main effect for location, $F(1, 13) = 5.08$, $p < .05$, $\eta p^2 = 0.28$, indicating that participants spent longer fixating on the goalkeeper ($M = 0.55$ ms, $SD = 0.43$) compared with the goal target area ($M = 0.27$ s, $SD = 0.19$). The interaction between condition and location was also found to be significant, $F(1, 13) = 4.98$, $p < .05$, $\eta p^2 = 0.28$. Post hoc t tests with a Bonferroni correction ($p < .025$) revealed that mean fixation duration to the goalkeeper was significantly longer, $t(13) = 2.69$, $p < .025$, $d = 0.41$, in the high-threat ($M = 0.34$ ms, $SD = 0.30$) as opposed to the low-threat condition ($M = 0.22$ s, $SD = 0.14$). A borderline significant difference, $t(13) = 2.51$, $p = .026$, $d = 0.74$, with a moderate-to-large effect size, was found between the mean fixation duration between the goalkeeper ($M = 0.34$ ms, $SD = 0.30$) and goal locations

(M = 0.14 ms, SD = 0.12), in the high-threat condition. The mean fixation duration data are presented in Figure 7.
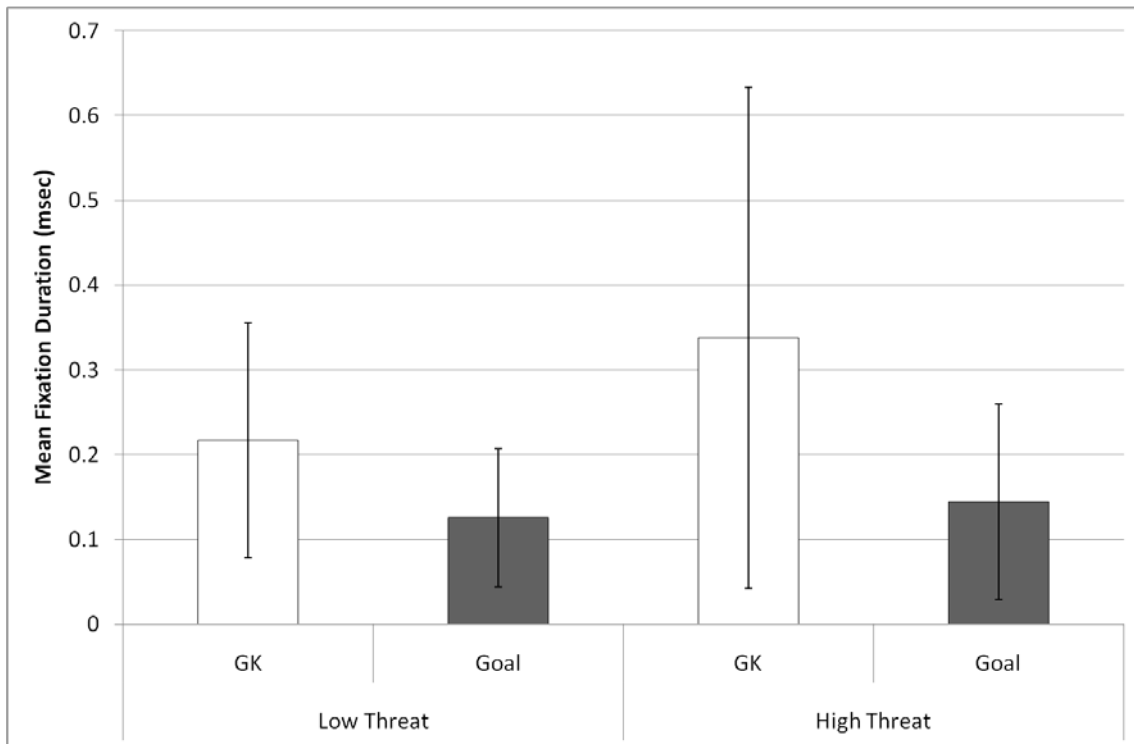
Figure 7. Gaze behaviour data, showing the mean fixation duration (in milliseconds) for each location under low- and high- threat conditions (with standard error of the mean).

Time to First Fixation on the Goalkeeper. A paired samples t test revealed that participants were significantly quicker to fixate on the goalkeeper, $t(13)$ = 2.26, $p < .05$, d = 0.34, in the high-threat (M = 2.45 s, SD = 0.69) compared with low-threat condition (M = 2.68 s, SD = 0.66).

Preparation Time. A paired samples t test revealed that there was no significant difference, $t(13)$ = .079, p = .44, d = 0.09, in the mean preparation time (trial duration) for each of the seven shots across the low- (mean time of 4.66 s, SD = 1.17) and high-threat condition (mean time of 4.76 s, SD = 1.44).

Discussion

This study aimed to explore anxiety-induced attentional alterations contributing to suboptimal penalty kick performance, using ACT (Eysenck *et al*., 2007) as an overarching framework. The self-reported anxiety data support the effectiveness of the threat manipulation, although the intensity of threat experienced is almost certainly lower than typically experienced in "real" environments (e.g., penalty shoot-outs; see Jordet *et al*., 2006, 2007). However, the anxiety levels experienced were similar to those reported in Krane's (1994) validation studies, and other studies using the MRF (e.g., Wilson *et al*., 2006). Furthermore, the significant increase in reported anxiety was sufficient to have had a detrimental impact on participants' attentional control (as indexed by gaze behaviour) and shooting performance.

Attentional Control

According to ACT, anxious individuals preferentially attend to conspicuous or salient stimuli at the expense of goal-driven, task-relevant stimuli, owing to the increased influence of the stimulus-driven attentional control system (Eysenck *et al*., 2007). Three gaze measures were adopted to reflect potential differences in the way participants oriented toward, and maintained attention on, the two target locations in both conditions. When participants were anxious, there was a significant increase in the speed at which they first fixated on the goalkeeper, reflecting an attentional bias toward this target. As the goalkeeper adds uncertainty to the outcome of the task from the penalty taker's perspective, the goalkeeper is likely to be considered a source of threat to goal achievement.

The mean fixation duration data revealed significant main effects for condition and location and a significant interaction effect (Figure 7). Although both the goalkeeper and goal area were fixated on for longer in the high-threat as opposed to

low-threat condition, this effect was more pronounced for the goalkeeper: anxious participants preferentially attended to the goalkeeper. As there was no such interaction effect evident for the mean *number* of fixations to the goalkeeper (Figure 6), these findings suggest that anxiety caused participants to maintain their fixations on the goalkeeper for longer (disengage attention more slowly), as opposed to increasing distractibility. The lack of a significant difference in preparation time (trial length) between conditions, suggests that these changes in gaze measures were due to changes in attentional control and not simply due to participants taking longer in the high-threat condition. Together, the three findings therefore provide support for the predictions of ACT, as an increase in the emphasis of the stimulus-driven attentional system resulted in earlier and longer fixations to the conspicuous, goal-threatening goalkeeper and the utilization of a suboptimal strategy.

There are some caveats concerning our interpretation of the gaze data as being supportive of the predictions of ACT. First, the football penalty task does not provide as elegant a test of the conflict between a goal-driven strategy and stimulus-driven attentional control as a more "pure" cognitive task (e.g., the anti-saccade task; Derakshan *et al.,* 2009). Most research examining threat-related attentional biases has adopted protocols using some form of cueing paradigm (see Bar-Haim, Lamy, Pergamin, Bakermans-Kranenburg, and van IJzendoorn, 2007). This is not possible with a penalty task, as the goalkeeper is located in the same, centralized location for all trials. However, the findings do suggest that the goalkeeper, as a conspicuous and salient stimulus, has preferentially captured attention in the high-threat condition in a manner consistent with ACT's predictions.

Future research could build upon the current study by experimentally manipulating the salience and threat value of the goalkeeper and determining the impact

this has on attentional control (as in Derakshan *et al.*, 2009). The more salient and threatening the goalkeeper is, the greater the predicted influence of the stimulus-driven attentional control system. One way in which this salience could be manipulated is by adjusting the goalkeeper's starting position. Although large manipulations may not be ecologically valid, even small changes may impact upon the salience of this distracting stimulus. For example, previous research has demonstrated that even a marginally off-center goalkeeper may influence kick direction (Masters *et al*., 2007). Furthermore, research by van der Kamp and Masters (2008), examining the effect of the goalkeeper's arm positions while standing (arms by side, or stretched out) found that this affected penalty shot judgments. The goalkeeper could also be made more salient by making him more distracting (e.g., by waving his arms, or jumping on the spot) or by adjusting the color of his shirt. Research in sport settings has found that red shirts confer an advantage, perhaps because the color red has evolved to signify dominance (e.g., Greenlees, Leyland, Thelwell, and Filby, 2008; Hill and Barton, 2005).

The second concern with our interpretation is that, even though there was a significant interaction effect for mean fixation duration, participants spent longer fixating on the goalkeeper than on the goal target area irrespective of condition (Figure 7). We expected a clearer interaction effect, with participants fixating for longer on the target goal spaces when not anxious (reflecting top–down, goal-directed attentional control), but becoming more stimulus driven in the threatening condition. So, why did the goalkeeper capture attention in both conditions? First, the goalkeeper takes up a large proportion of the target area (see Figure 5), and he is the only conspicuous and moving stimulus in the environment. Second, it is possible that participants were checking for advance cues as to which way the goalkeeper might move (Kuhn, 1988). Van der Kamp (2006) has previously suggested that a goalkeeper-focused strategy may be useful if the keeper makes an early decision to dive one way, leaving the other side

of the goal unprotected. However, as the goalkeeper did not move until penalties had been struck, this would not appear to be an effective strategy (see performance results).

As non-anxious participants did not consistently adopt a single goal-driven strategy, it is difficult to accurately determine the balance between top–down (goal-driven) and bottom–up (stimulus driven) attentional control. The anti-saccade task used by Derakshan *et al.* (2009) had specific top–down instructions, so differences in top–down and bottom–up control were easily determined. Future studies using a penalty task should therefore explicitly manipulate the top–down control aspect of each penalty kick by varying the payoffs for an optimal strategy. This would enable a stricter definition of what goal-directed control should be for the task, and more effectively create the conflict between salient stimuli and an optimal top–down strategy.

The goal-directed attentional control could be manipulated by creating optimal scoring zones where the incentive is greater (e.g., the top-left corner might be worth10 points as opposed to 1 point for scoring a goal elsewhere). The importance of aiming toward the goal corner could also be manipulated by penalizing shots that are saved (e.g., –10 points), more than shots that narrowly miss the target (e.g., 0 points). ACT would predict that, as anxiety impairs attentional flexibility at the expense of bottom–up, stimulus-driven control, anxious individuals would be less successful at adjusting their attentional strategies to meet varying top–down objectives.

A final caveat is that other more descriptive attentional theories could possibly explain the findings that heightened anxiety caused attention to be directed centrally to the goalkeeper. First, Wegner's (1994) theory of ironic processing purports that the instruction to avoid a thought or action may ironically increase the tendency to engage in this thought or action, especially when attentional resources are taxed. Bakker *et al.* (2006) have previously shown that under time pressure, footballers may look toward the

goalkeeper despite instructions not to. Second, Easterbrook's (1959) cue utilization hypothesis suggests that increased arousal narrows attention, restricting the range of incidental cues that are used (i.e., the attentional field narrows). Janelle *et al.,* (1999) found support for attention-narrowing effects that were due to heightened anxiety in an auto racing simulation in which participants were less successful at detecting peripherally presented targets when anxious, while central task performance was maintained.

It is difficult to discount these other postulations for this particular task involving a centralized source of threat. However, Easterbrook's predictions have not always been supported (see Eysenck, 1982, for a review), and ACT can be considered a more overarching framework for anxiety and attentional biases. Compared with Wegner's theory of ironic processing and Easterbrook's cue utilization hypothesis, ACT is more closely linked to other theoretical developments of anxiety and visual attention (Bar-Haim *et al.*, 2007; Weierich *et al.*, 2008). In addition, as Eysenck *et al.* (2007) suggest, ACT's predictions are related to a major theoretical approach to attention (Corbetta and Schulman, 2002), which is not the case for the other two theories. By experimentally manipulating the top–down strategic nature of the task, and the salience of the distracting goalkeeper, as we have already suggested, future studies may provide stronger comparative tests of the predictions of these three attentional control theories.

Performance

In developing ACT, Eysenck *et al.* (2007) maintained the prediction from PET that anxiety would have a greater impact on processing efficiency than on performance effectiveness (see Derakshan *et al.*, 2009). In the current study, when gaze was constrained centrally (toward the goalkeeper), shots were also hit more centrally (by a mean of 14 cm) and therefore closer within the goalkeeper's reach. Impairments in the

efficiency of attentional control (more stimulus driven) therefore resulted in subsequent impairments in performance (accuracy of shots). The findings of the current study therefore reinforce those from Wilson, Vine and Wood (2009) study of basketball free throw shooting and may reflect the critical interdependence between attention and performance in far aiming tasks. These results are also in agreement with those of chapter 2 which found that resultant shot location was closely linked to final aiming fixation locations. Participants tended to look where they aimed, with centrally focused fixations inducing more central ball placements.

It is important to note that despite this impairment in where the ball was hit, participants were actually reasonably successful at *scoring* penalties; on only 14 occasions did the goalkeeper make a save (8 in the no-threat and 6 in the high-threat condition). The fact that the goalkeeper was prevented from anticipating shot direction is likely to have influenced this result, and, as there was no prize money available to the goalkeeper, so might have motivational factors. However, including shots that missed the target (four in the no-threat, six in the high-threat condition), there was an 86% success rate across both conditions similar to the 80% success rates reported in real-life penalty kicks (Bar-Eli, Azar, Ritov, Keidar-Levin, and Schein, 2007). Therefore, the performance of the goalkeeper and kickers does not seem completely at odds with what we might expect from more ecologically valid, 11-a-side kicks. In addition, these experienced participants would not have found their success ratio to be unrealistically high, thereby maintaining their levels of uncertainty with regards to goal outcome.

Whereas the task was representative of a 5-a-side penalty kick, care must be taken in applying the findings directly to the performance of 11-a-side penalties. The decision to use a 5-a-side goal was made to provide the strictest possible internal control for testing the predictions of ACT in an applied environment. Because 5-aside penalties

do not incorporate a run-up before kicking, differences in run-ups between kickers and in the timing of gaze behaviour while running up to the ball did not have to be accounted for. We would expect a more dynamic situation to occur during the run-up in the 11-a-side game, with the penalty taker's attention perhaps switching between the goal target areas, goalkeeper, and the ball during the run-up.

With a full run-up, the final fixation to the ball before initiating the kicking action (i.e., the quiet eye period; Vickers, 1996) would also likely play a more important role in ensuring an accurate ball strike (see Vickers, 2007). Fixations to the ball were not analyzed in the current study since we were more interested in examining differences in the fixations to the target locations across conditions. As a result of the one-step nature of the shot, fixations to the ball were not critical to ensure accurate contact. Indeed, of the 167 kicks analyzed, on only 32 occasions (15 in the low- and 17 in the high-threat condition) did the kicker fixate on the ball while shooting. Therefore, 81% of shots had no fixation on the ball after an initial check of its placement on the spot, and were executed while the participants looked toward the target area (goal/goalkeeper).

Although more research is required to further our understanding of why performers may miss penalties in evaluative situations, the results found in the current study, along with those of Bakker *et al*. (2006), van der Kamp (2006), and chapter 2, would suggest that inappropriate attention to the goalkeeper is a major factor. Indeed, recent anecdotal evidence from the top level of the 11-aside game also supports this interpretation. In the 2009 FA Cup semifinal, Dimitar Berbatov (a £30 million forward for Manchester United) missed a penalty in the sudden death shoot-out by feebly hitting his shot directly at the goalkeeper. He was derided in the press for his poor attempt and rationalized his miss as follows: "I was looking for the goalkeeper and in the last

moment he took the angle I was going for, so he saved it" (Berbatov, 2009). If under pressure, players are more likely to find the goalkeeper attention grabbing, a gaze-training intervention designed to direct attention to the target areas of the goal may help maintain a sense of control and reduce uncertainty in these situations. Future research may attempt to test the validity of such training programs for protecting against attentional disruptions that are due to increased anxiety.

To conclude, experienced footballers looked at the goalkeeper significantly earlier and for longer periods when anxious, with these changes in attentional control negatively influencing resultant shot placement. These results are supportive of anxious individuals having an attentional bias toward threatening stimuli, probably owing to a disruption in the balance between the goal-directed and stimulus-driven attentional control systems. These findings add support to the predictions of ACT (Eysenck *et al*., 2007) in motor task performance under pressure and may offer a mechanistic explanation as to why penalty kicks are missed in pressure environments.

Chapter 4: A Moving Goalkeeper Distracts Penalty Takers and Impairs Shooting Accuracy

Introduction

"The biggest memory I have is the 1984 European Cup final against Roma and my 'spaghetti legs' routine during the penalty shoot-out that won us the trophy. People said I was being disrespectful to their players, but I was just testing their concentration under pressure. I guess they failed that test."

Bruce Grobbelaar, Former Liverpool F.C Goalkeeper (in Jackson, 2005)

The outcome of important football matches is often decided by penalty kicks and the frequency of these tie-break scenarios has increased since their first introduction in 1974 (Armatas *et al.,* 2007; Miller, 1996). Due to this increase, and the financial incentives for success in today's professional game, players strive to gain any advantage when taking part in such events. In particular, goalkeepers frequently incorporate strategies that are designed to disrupt, delay or distract the kicker during the preparation and execution of the kick. In one recent study, Jordet *et al.,* (2009) found that players that were delayed from taking their penalty kick, often by the goalkeeper, were more likely to miss. However, to date, no empirical evidence exists to ascertain what effect distractions have on the visual attention and performance of footballers taking penalty kicks under pressure.

Research from general psychology would suggest that distracters have a detrimental impact upon cognitive performance, particularly in highly pressurised environments (Eysenck *et al.,* 2007). Additionally, there is a strong body of evidence which shows that anxiety is associated with: (a) an attentional bias towards, and an inability to 'disengage' from, the processing of threat-related distracters; and (b) an enhanced distractibility in the presence of task-irrelevant threatening stimuli (see Bar-

Haim *et al*., 2007, for a review). Attentional Control Theory (ACT: Eysenck *et al*., 2007) attempts to encompass these attentional disruptions into a unified framework. ACT's primary assumption is that attentional control is characterised by two attentional systems: top-down, goal driven attentional control, influenced by current goals, expectations and knowledge; and bottom-up, stimulus driven attentional control, influenced by salient or conspicuous stimuli (Corbetta and Shulman, 2002). According to ACT, anxiety disrupts the balance between these two attentional systems by increasing the influence of the stimulus driven attentional system at the expense of the more efficient goal driven system; especially in the presence of threat-related distracting stimuli (Eysenck *et al*., 2007; Eysenck and Derakshan, in press).

The results of study 2 also found that this anxiety-induced disruption to attentional control brought about significant decreases in shooting accuracy. Specifically, the participants' centralised gaze also produced shots that were hit significantly closer to the goalkeeper (see also Bakker *et al*., 2006; Binsch *et al.,* 2010). These findings have led researchers to suggest that, in order to hit an accurate penalty kick, players should align gaze with aiming intention (Bakker *et al*., 2006; van der Kamp, 2006; Chapter 2 and 3). Indeed, neuroscience researchers have suggested that the neural mechanisms regulating goal-directed movements profit from the accurate and timely spatial information of the foveated target (Land, 2009; Neggers and Bekkering, 2000).

If, as suggested by ACT, an anxious performer is more easily distracted by threat-related task-irrelevant stimuli, then task-relevant information necessary for accurate shooting will be unavailable for the planning of responsive motor actions, and performance may breakdown (see Wilson, Vine, and Wood, 2009). Therefore, from a goalkeeper's perspective, distracting a kicker's attention may have real benefits in

increasing the likelihood of an inaccurate shot. Furthermore, according to ACT, the effectiveness of such distractions is likely to be more pronounced under pressurised situations such as penalty kicks. However, in previous studies examining the gaze behaviour of football penalty takers researchers have adopted a modified task, incorporating only a one-step run up (Bakker *et al*., 2006; Binsch *et al*., 2010; Nagano *et al*., 2006; Chapter 3), and consequently, it is difficult to determine if the distracting effect is most pronounced during the aiming phase or during the execution phase (i.e., run-up). The aim of this study was therefore to explore the effectiveness of goalkeeper movements in distracting penalty takers under pressure.

During the aiming phase, and in line with the predictions of ACT and the finding of chapter 3, it was hypothesised that anxious participants would fixate on a moving goalkeeper more often (increased distractibility) and for a longer duration (disengage more slowly) than to a stationary goalkeeper. This disruption in attentional control should produce shots that are hit closer to the goalkeeper (as Bakker *et al*., 2006; Chapter 3).

Predictions regarding the attentional control of shooters during the run-up are somewhat exploratory, but it is expected that participants will fixate on the ball in order to ensure an accurate contact. Such visual behaviours are indicative of superior performance in tasks with two abstract targets (e.g., ice hockey shooting; Vickers, 2007; and golf putting; Vickers, 1992; Wilson and Pearcey, 2009). As well as the location of the last fixation, its duration (Quiet-eye; QE) has been shown to be important in a variety of aiming-based tasks, and can be negatively impacted (i.e., reduced) by anxiety (Vickers, 2007; Wilson, 2008). It was therefore hypothesised that during the execution phase (i.e., the run-up), participants would fixate predominately on the ball, but the total

time spent looking at the ball and the duration of the last fixation on the ball was expected to shorten under conditions of threat and goalkeeper movement.

Methods

Participants

Eighteen university footballers (mean age = 20.2 yrs, *SD* = 0.8) volunteered to take part. All had experience of playing competitive football (mean years = 9.9, *SD* = 3.2) and rated their penalty kicking ability to range from 5-8 (mean rating = 6.2, *SD* = 0.9) on a scale of 0 to 10. A local ethics committee approved the study before any testing was carried out and written consent was obtained from all participants prior to the commencement of any procedures.

Apparatus

A standard, full sized (7.32 m wide x 2.44 m wide), football goal was marked on a wall and participants shot penalty kicks from the standard distance of 11 meters from its centre. The goal was split into 12 x 4, 61cm squares to aid the rating of performance error. Gym mats (32mm) covered the goal area to prevent injury to the goalkeeper when repeatedly diving (Figure 8). A standard size 5 Nike Duravel football of standard inflation was used throughout all trials. Participants were fitted with the Mobile Eye tracker (see Chapter 1) and this was calibrated for each participant using a firewire cable connected to the laptop. When calibrated, the firewire cable was removed allowing the eye tracker, and participant, to be fully mobile. Data was saved to DV tape on the DVCR and downloaded to the laptop for offline analysis.

Measures

State anxiety. The anxiety thermometer was used to assess the self-reported levels of state anxiety experienced by the participants in the low and high threat

conditions (Houtman and Bakker, 1989). This 10cm scale ranges from 0 (not at all anxious) to 10 (extremely anxious) and was chosen because it offers a rapid assessment of state anxiety, unlike more popular self-reported anxiety measures (e.g., CSAI-2; Martens *et al.,* 1990). Furthermore, this inventory does appear to correlate with cognitive and somatic anxiety reported on the CSAI-2, with coefficients of 0.59 and 0.62 respectively, and has been used in other studies that have explored anxiety's effect on attentional control (Nieuwenhuys *et al.,* 2008).

Performance. In order to minimise the influence of goalkeeper performance on results, a measure of target accuracy was adopted in conjunction with totalling the number of saved and missed shots. Target accuracy was measured depending on where on the goal the ball hit, with this location being given a horizontal (x) coordinate (as Chapter 3). Each half of the goal consisted of 6 zones of 61cm, starting from an 'origin' in the centre (0 cm) and moving out to 366cm at each post. Higher scores therefore reflected shots that were placed further from the goalkeeper's reach where they would have more chance of scoring. The coordinate was determined via frame-by-frame analysis of the eye-tracker video file using GazeTracker analysis software (Eye Response Technologies, VA, USA) with a precision of 5cm (approximately one quarter the diameter of the ball). Shots that missed the target were not given an accuracy score. Shots that were saved were given an estimated accuracy score reflecting where they were predicted to hit on the goal area. Estimates of shooting accuracy from a sample of 40 shots (8 saves and 32 goals) had an inter-rater reliability of 98.3%.

Pre-shot duration. The time taken to prepare and execute the shot (trial duration) was calculated in seconds, via frame-by-frame analysis. Trial onset began the instant the kicker took his hands away from the ball, after placing it on the penalty spot, and ended on foot to ball contact. The 'aiming phase' of the penalty kick began when the

participant made his first target-focused fixation (goalkeeper or goal) and ended when the 'execution phase' began on the initiation of the run up.

Total number of fixations. This measure was designed to reflect the distractibility of the participants between the relevant target locations (goalkeeper, goal and ball). More fixations to any one area may highlight heightened distractibility to that area of the visual workspace (Wilson, Vine and Wood, 2009). The total number of fixations was calculated separately for both the aiming (prior to run-up) and execution (run-up) phases of each kick.

Total viewing time. This is a measure of the total (cumulative) amount of time (milliseconds) spent fixating at each target location, in each trial. This measure was designed to reflect attentional disengagement; the extent to which attention was grabbed and maintained by each location. Total viewing time to each location was calculated separately for both the aiming (prior to run-up) and execution (run-up) phases of each kick.

Last fixation duration on the ball. This measure was designed to reflect the quiet eye period for the penalty kick and was defined as the duration (in milliseconds) of the last fixation on the ball prior to foot-to-ball contact. The ball was chosen because such visual behaviour is apparent in aiming tasks that incorporate shooting to abstract targets (see Vickers, 2007).

Experimental Conditions

Participants took ten practice kicks to the goal with no goalkeeper present to prevent any prior learning from both parties. They then took five kicks under low and high threat counterbalanced conditions, in a repeated measures research design. In the low threat condition, non-evaluative instructions were provided to participants, asking

them to do their best but stressing that the research was testing the reliability of the eye tracker. In the high threat condition, participants were made aware of a £50 prize for the kicker with the highest accumulated score and were told that a league table with each participants name and score would be circulated between all participants.

The instructions to the goalkeeper were that he was not to move along his goal line or make an attempt to anticipate ball direction until each shot was struck. On kicks 1, 3 and 4 in each threat condition the goalkeeper was asked to stand directly in the centre of the goal, with knees bent and arms by his side (i.e., stationary). These variables were standardised as previous research has shown that they may affect shooting performance in this task (Masters *et al*, 2007; van der Kamp and Masters, 2008). For the 'moving' goalkeeper manipulation he was asked to wave his arms up and down during the pre-shot duration on shots 2 and 5 in each threat condition (see Figure 8).

Figure 8. A screen grab from the Gazetracker software environment showing the experimental setup and each 'LookZone' for the goalkeeper (A; in the distraction process), goal (B) and ball (C).

Procedure

Participants attended individually and, after giving their written consent, were told that the aim of the study was to compare kicking performance under different conditions. After taking their practice kicks, the participants were fitted with the eye tracker and this was calibrated using each corner of the goal, the centre of the goal and three other points that were marked above each post and centre of the goal.

Participants were then provided with instructions related to the condition in which they were going to perform, and subsequently completed the anxiety thermometer before taking three of the five penalty kicks for that condition. In the threat condition, after these initial three kicks participants were told that the kicks they had

just taken were worth one point. They were then told that their remaining two kicks would be worth three points each and if they were to win the prize money, it was important to score at least one of these kicks. This information was incorporated to re-affirm the anxiety manipulation which was expected to diminish over repeated trials. The relevant instructions were then reiterated and the anxiety thermometer completed again before the final two kicks were taken in both low and high threat conditions. Before each kick participants stood on the penalty spot, with ball in hand, and a calibration check was performed.

Data Analysis

Point of gaze data (consisting of avi. and csv. files) from the Mobile Eye were analysed using GazeTracker Software (Eye Response Technologies, VA, USA). A "LookZone" was created around the goalkeeper, the goal and the ball and these were manipulated in a frame-by-frame fashion (Figure 8). The software then automatically measured the total number of fixations and total amount of time spent within these pre-established LookZones. A fixation was classified as three or more consecutive frames (≥ 120 ms) in which the cursor stayed in the same location (Vickers, 1996).

Self-reported mean anxiety scores were analysed using a paired samples *t*-test across low and high threat conditions. Two repeated measures 2 x 2 x 2 ANOVA's (threat x goalkeeper movement x location) were carried out to explore differences between the total number of fixations and total viewing time made to the goalkeeper and goal during the aiming phase of the kick. ANOVAs were also performed on the fixation data for the execution phase; however this involved the analysis of three locations (goalkeeper, goal, and ball). Shooting accuracy, the number of shots missed, the number of shots saved, trial duration and the duration of last ball fixation data were subjected to 2 x 2 (threat x goalkeeper movement) AVOVAs. Due to the differing number of kicks

taken with a stationary and moving goalkeeper, the total number of kicks missed and saved was divided by the total number of kicks taken in each condition. These were expressed as percentages and were subjected to log transformations to normalise the data before analysis. Where sphericity was violated, Greenhouse-Geisser corrections were applied. All relevant interactions and main effects were followed up using Bonferroni corrected, paired samples t-tests and effect sizes were calculated using Partial Eta squared (η_p^2) for omnibus comparisons and Cohen's d for pairwise comparisons.

Results

State Anxiety

Paired samples t-test revealed that the participants were significantly more anxious, $t(17) = -8.04$, $p < .001$, $d = 1.6$, in the high threat (mean = 5.22, $SD = 1.44$) compared to the low threat condition (mean = 2.86, $SD = 1.21$).

Performance

Shooting accuracy. No significant main effect was found for threat, $F(1,17) = 0.56$, $p = .47$, $\eta_p^2 = .0.32$. A significant main effect was evident for goalkeeper movement, $F(1,17) = 7.54$, $p < .05$, $\eta_p^2 = .31$, with shots centralising (by 32cm) in stationary (mean = 251.20 cm, $SD = 54.63$) compared to moving goalkeeper trials (mean = 218.82 cm, $SD = 64.10$). The interaction between threat and goalkeeper movement was not significant, $F(1,17) = 0.21$, $p = .65$, $\eta_p^2 = .01$, (Figure 9).

Missed shots. Participants did not miss the target more often (shoot wide or over the goal) due to the influence of threat, $F(1,17) = 1.83$, $p = 0.19$, $\eta_p^2 = .09$, or goalkeeper movement, $F(1,17) = 0.44$, $p = 0.52$, $\eta_p^2 = .03$, and there was a non-significant interaction effect, $F(1,17) = 0.11$, $p = .74$, $\eta_p^2 = .01$, (Figure 9).

Saved shots. Exploration of shots that the goalkeeper saved revealed no significant main effect for threat, $F(1,17) = 0.68$, $p = .42$, $\eta_p^2 = .04$, but the number of saves the goalkeeper made significantly increased when he moved, $F(1,17) = 4.60$, $p < .05$, $\eta_p^2 = .21$. No significant interaction was evident, $F(1,17) = 0.71$, $p = .41$, $\eta_p^2 = .04$, (Figure 9).

Pre-shot Duration

No significant main effects were evident for threat, $F(1,17) = 2.91$, $p = .11$, $\eta_p^2 = .15$, or goalkeeper movement, $F(1,17) = 0.03$, $p = .87$, $\eta_p^2 = .00$, and the interaction was also found to be non-significant, $F(1,17) = 1.04$, $p = .32$, $\eta_p^2 = .06$. This suggests that any attentional and performance differences found are not simply due to participants taking longer in any one condition. Mean pre-shot durations were approximately 6 seconds (mean $= 6.27$, $SD = 1.81$ seconds).
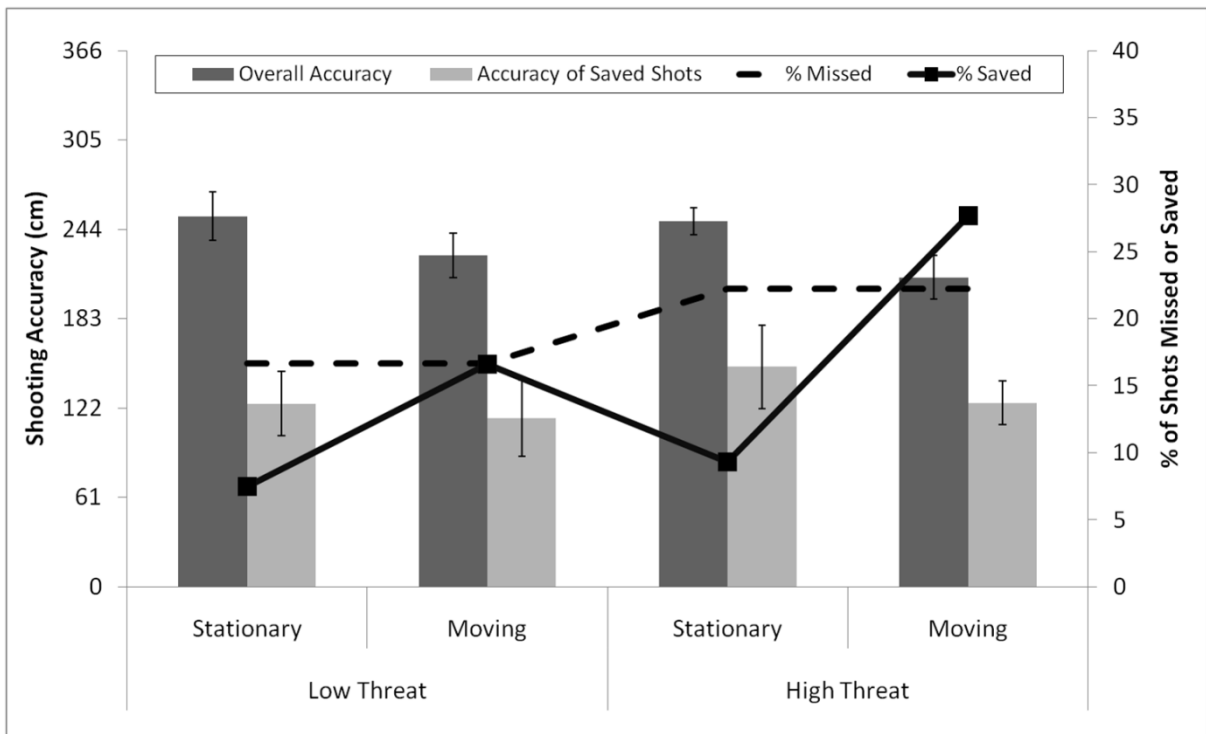

Figure 9. Performance data showing the overall shooting accuracy (distance from the centre of the goal), the accuracy of shots that were saved and the total percentage of shots that were saved across threat and goalkeeper movement conditions.

Attentional Control: Aiming Phase

Due to technical issues with the eye-tracker, the gaze data for one participant was invalid and was therefore removed from further analyses.

Total number of fixations. A significant main effect was found for threat, $F(1,16) = 14.15$, $p < .01$, $\eta_p^2 = .47$, indicating that there were significantly more fixations in the high threat compared to the low threat condition. No significant main effects were found for goalkeeper movement, $F(1,16) = 0.98$, $p = .34$, $\eta_p^2 = .06$, or location, $F(1,16) = 0.67$, $p = .04$. $\eta_p^2 = .01$. The interaction between goalkeeper movement and location was the only significant interaction present, $F(1,16) = 29.11$, $p < .01$, $\eta_p^2 = .66$. Bonferroni corrected paired samples t-tests revealed that when the goalkeeper was moving, participants made significantly more fixations, ($p < .00$) towards him (mean = 2.10, $SD = 1.20$) compared to when he was stationary (mean = 1.17, $SD = 1.01$). Furthermore, participants fixated significantly more often, ($p < .025$), on the goal target area when the goalkeeper was stationary (mean = 2.26, $SD = 1.96$) compared to when he was moving (mean = 1.63, $SD = 1.37$, Figure 10).

Total viewing time. A significant main effect for threat was found, $F(1,16) = 11.50$, $p < .01$, $\eta_p^2 = .42$, indicating that there were significantly longer periods of time spent fixating targets in the high threat (mean = 462, $SD = 386$ ms) than low threat condition (mean = 347, $SD = 380$ ms). Non-significant main effects were found for goalkeeper movement, $F(1,16) = 2.57$, $p = .13$, $\eta_p^2 = .14$, and location, $F(1,16) = 0.76$, $p = .40$, $\eta_p^2 = .45$. A three way interaction between threat, goalkeeper movement and location was evident, $F(1,16) = 6.80$, $p < .05$, $\eta_p^2 = .30$. As predicted, there were significantly longer periods of time spent fixated on the goalkeeper in the high threat, moving goalkeeper condition than to other locations, or to the goalkeeper in other conditions (all $ps < .01$; see Figure 10).

Figure 10. Gaze behaviour data during the aiming phase of the kick, showing the mean total viewing time (ms) and mean number of fixations to each location (GK and Goal) under threat and goalkeeper movement conditions (with s.e.m.s).

Attentional Control: Execution Phase

Total number of fixations (Figure 11). ANOVA revealed no significant main effects for threat, $F(1,16) = 1.09$, $p = .32$, $\eta_p^2 = .06$, or goalkeeper movement, $F(1,16) = 0.00$, $p = .97$, $\eta_p^2 = .00$. A significant main effect was found for location, $F(1.02,1632) = 54.81$, $p < .001$, $\eta_p^2 = .77$. Paired samples t-tests showed that during the run up there were significantly more fixations to the ball (mean = 1.81, $SD = 0.14$) compared to the goalkeeper (mean = 0.00, $SD = 0.01$) and goal (mean = 0.05, $SD = 0.03$; $ps < .001$). All other interactions were non-significant ($ps > .05$; Figure 11).

Total viewing time. ANOVA revealed no significant main effects for threat, $F(1,16) = 0.09$, $p = 0.77$, $\eta_p^2 = .01$, or goalkeeper movement, $F(1,16) = 1.66$, $p = 0.22$, $\eta_p^2 = .09$. A significant main effect was found for location, $F(1.01,8.06) = 30.43$, $p < 0.00$, $\eta_p^2 = .66$. Paired sample t-tests showed that during the run up participants spent

longer (ps < 0.00), looking at the ball (mean = 430, SD = 60 ms) compared to the goalkeeper (mean = 0, SD = 0 ms), and the goal (mean = 0, SD = 0 ms). All other interactions were non-significant ($p > 0.05$; see Figure 11).

Last fixation duration on the ball. No significant main effects were found for threat, $F(1,15) = 1.09$, $p = .31$, $\eta_p^2 = .07$, or goalkeeper movement, $F(1,15) = 1.29$, $p = .27$, $\eta_p^2 = .08$, and the interaction was also found to be non-significant, $F(1,15) = 1.31$, $p = .27$, $\eta_p^2 = .08$. Mean durations were in the order of 200 ms (mean = 230, SD = 103 ms).
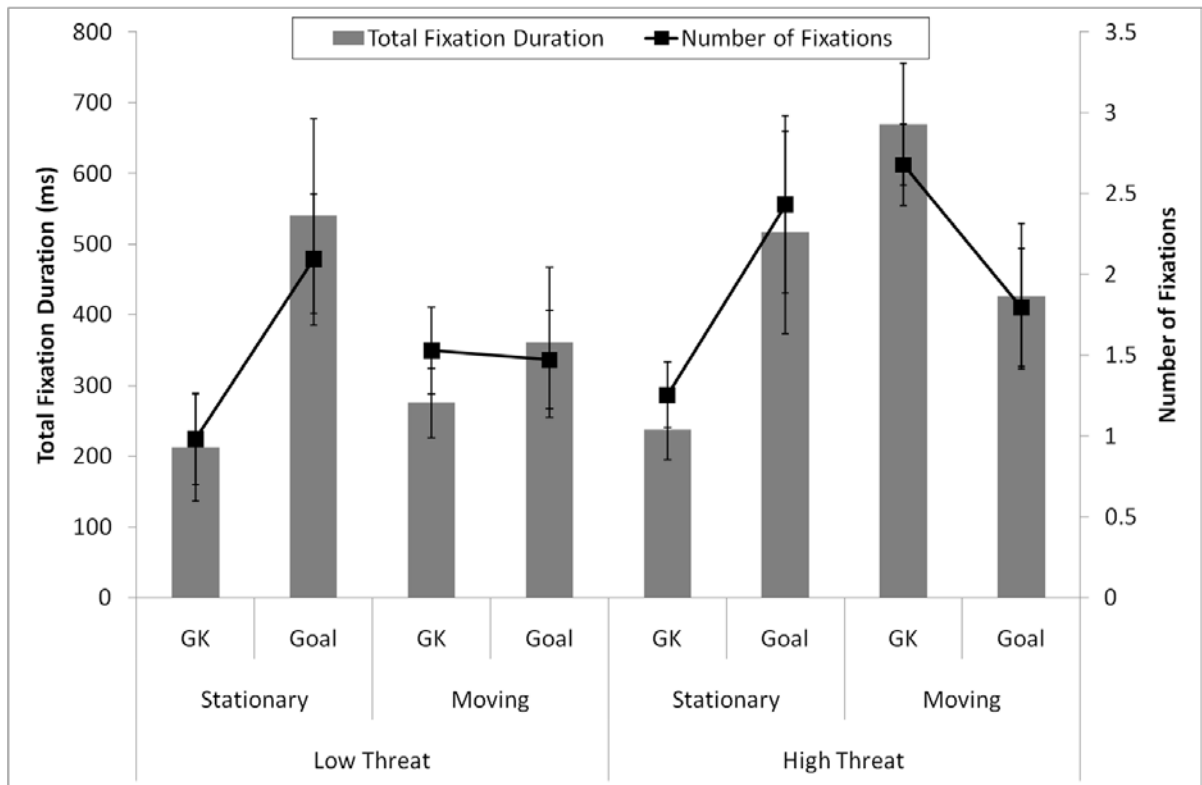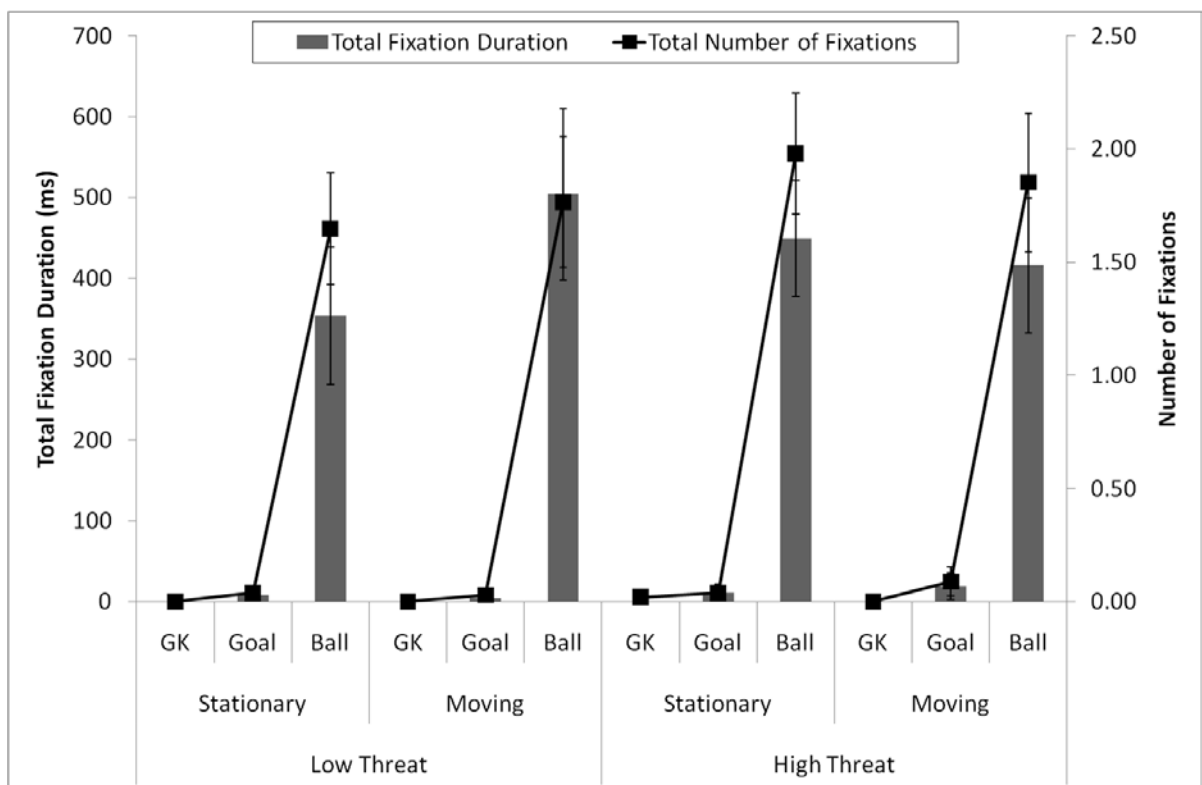

Figure 11. Gaze behaviour data during the execution phase of the kick, showing the mean total viewing time (ms) and mean number of fixations to each location (GK, Goal and Ball) under threat and goalkeeper movement conditions (with s.e.m.s).

Discussion

The predictions of ACT (Eysenck *et al.*, 2007) have been tested in a range of visuomotor tasks such as basketball free-throw shooting (Wilson, Vine *et al.*, 2009), climbing (Nieuwenhuys *et al.*, 2008), police firearms response (Nieuwenhuys and

Oudejans, 2009) and modified football penalty shooting (Chapter 3). However, this is the first study that has attempted to manipulate the degree of salience of any external, distracting stimuli; in this instance the goalkeeper. The aim was to discover if a moving goalkeeper would distract anxious penalty takers, and if so, whether this disruption in attentional control would impair shooting performance.

The anxiety manipulation was deemed successful, although the intensity of the threat experienced was expected to be less than that experienced in 'real' penalty shootouts (Jordet *et al*., 2006, 2007). However, the intensity of the anxiety experienced was sufficient to have had a detrimental impact on the attentional control of the participants, although not performance *per se*, and is similar to levels reported in other laboratory-based studies that have used this inventory (e.g., Nieuwenhuys *et al*., 2008; Pijpers *et al.,* 2003).

Performance

While it was predicted that we would find significant interactions for shooting accuracy and the number of saved shots between threat and goalkeeper movement conditions, no such interactions were evident. A moving goalkeeper had a significant effect on the frequency of saved shots and the shooting accuracy of penalty takers regardless of threat (Figure 9). A possible explanation for this finding may be that the effect of increasing the salience of the goalkeeper, by increasing his movements, diluted any additional effect of the anxiety manipulation. Indeed, previous research has suggested that the mere presence of a goalkeeper can influence the aiming intention and accuracy of penalty takers, even when anxiety is not manipulated (Chapter 2).

Attentional Control: Aiming Phase

It was hypothesised that when anxious, participants would fixate on a moving goalkeeper more often (increased distractibility) and for a longer duration (disengage more slowly) than when shooting to a stationary goalkeeper. Findings from the gaze measures adopted provide some support for these hypotheses. In short, the results indicated that the participants were more distracted by a moving goalkeeper than a stationary one and struggled to disengage from a moving goalkeeper under situations of high threat (see Figure 10). Therefore, it seems that a moving goalkeeper has a similar level of distractibility across low and high threat conditions but when anxious, participants found it difficult to disengage from this threat-related distraction. These findings are entirely consistent with ACT, with anxious individuals displaying a shift in attentional control from a target-focused, top-down attentional strategy (goal focused), to stimulus-driven (goalkeeper-focused) bottom-up attentional control (Eysenck and Derakshan, in press).

Attentional control: Execution phase

While the results for the aiming phase supported the predictions of ACT (Eysenck *et al*., 2007) the effect of anxiety on attentional control during the run-up had not been previously examined. It was hypothesised that the primary objective of the run-up was to successfully guide the performer towards the ball and had little to do with extracting information from the environment in relation to choosing an aiming location (see Vickers, 1992; Wilson and Pearcey, 2009). During the run-up phase of a penalty kick, it is clear that the primary focus of the kicker's attention is directed towards the ball, which is consistent across threat and goalkeeper movement conditions (see Figure 11). This contradicts previous research utilising a one-step run-up, which has consistently shown that prior to shooting, penalty takers tend to focus on target specific

information (goalkeeper or goal) and pay little or no attention to the ball (Bakker *et al*., 2006; Nagano *et al*., 2006; Chapter 3).

The dependence on the ball as a source of visual information during the execution phase of a penalty kick can be explained with reference to vision's role in the guidance of action. In order to ensure an accurate ball contact, the eyes steer the performer towards the ball, thus providing the motor system with appropriate directional guidance (Land, 2009). Such visual behaviour is typical of abstract aiming tasks where an object must be accurately struck towards another target (e.g., golf putting and ice hockey shooting). The ball/puck has been found to be the location of the quiet-eye fixation in these abstract aiming tasks (Vickers, 2007).

No significant differences were evident between the duration of last fixation to the ball across threat and goalkeeper movement conditions. With no external video footage available to define a critical movement, this is admittedly a crude attempt at exploring a 'quiet-eye' measure. Further research is warranted in this area in order to define the critical movement phase of a penalty kick and explore how the quiet-eye period may change under pressure (Vickers, 2007). These results do suggest however, that during the run-up, a kicker's attention is primarily fixated on the ball and these data appear to add no additional explanation for potential anxiety-induced changes in attention and performance in penalty shooting.

As a moving goalkeeper impaired attentional control during the *aiming* phase, and shooting accuracy in a similar direction (i.e., centrally), it would appear that this is the critical period for constructing the aiming intention-shooting accuracy relationship. This aiming information must be stored during the execution phase (when gaze is located on the ball) if it is to guide subsequent shooting direction. While many goal-directed movements are guided online with visual control (Land, 2009; Neggers and

Bekkering, 2000), there is support for the role of a visual memory buffer in the planning of a variety of motor tasks (see Hayhoe, Shrivastava, Mruczek, and Pelz, 2003; Land and Furneaux, 1997). Gaze, intention and motor control can therefore be temporally dissociated and information from prior 'look-ahead' fixations (Pelz and Canosa, 2001) used to guide subsequent actions.

Vickers' (1996) conceptualisation of the quiet-eye as being a period of time when the force and direction commands of the task are computed without outside distraction appears to support this explanation. The purpose of predominantly ball-focused attention during the run-up may be to preserve earlier aiming information (from the aiming phase) and prevent its disruption. This period would also provide time for the transformation of sensory (target) information into an appropriate motor command (Sailer, Flanagan and Johansson, 2005); that is, where and how should the ball be struck to achieve the aiming intention.

Caution must be taken when attempting to transfer these findings to penalty kicks from professional football. First, as well as the limitation of a laboratory-based manipulation of threat, the skill level of the participants involved in this study is lower than professional players. It could be the case that professional players would show a greater resistance to the negative effects of distraction, although anecdotal evidence would suggest otherwise (e.g., Berbatov, 2009). Second, penalty takers usually only have one attempt, rather than the series of kicks taken in this study. Recent research suggests that penalty takers are likely to modify their aiming strategies when taking consecutive kicks in order to prevent the goalkeeper from learning anticipatory cues (Chapter 2). Future studies should therefore attempt to adopt a single-kick research design in order to address this limitation. Third, the prevention of anticipatory movements by the goalkeeper may have negatively influenced the number of saves that

he made. However, this internal control was necessary to reduce the likelihood of confounding variables influencing penalty takers' aiming strategies.

From a penalty taker's perspective, it seems that unwarranted attention to a goalkeeper is suboptimal for accurate shooting and more importantly, increases the likelihood of performance failure. Coaches and psychologists may wish to explore the utility of directing a kicker's attention to target-focused information during the aiming phase. Performance routines incorporating gaze-based elements may help to maintain effective attentional control while resisting threat-related distracters. Conversely, from a goalkeeper's perspective, attempting to distract penalty takers (especially during the aiming phase) may increase the likelihood of saving a subsequent shot by influencing aiming. Whether it is a 'spaghetti legs' routine or simply the waving of arms, it seems that Bruce Grobbelaar was right: a distracting goalkeeper does test the concentration of penalty takers. The participants in the current study also failed that test.

Chapter 5: Quiet Eye Training for Soccer Penalty Kicks

Introduction

Research has revealed that experts demonstrate a perceptual-cognitive and visuomotor advantage over less skilled performers; an advantage that is often underpinned by specific gaze strategies (Mann *et al*, 2007). These findings, coupled with recent advances in gaze registration systems, has lead to an increase in empirical studies that have attempted to explore how gaze may influence visual attention and subsequent performance in aiming tasks (see Vickers, 2007). Support for such methods is provided by research that suggests that in natural environments (such as sports) the location of gaze is driven by top down attentional control and dependent on specific task goals and demands (Land, 2009). Furthermore, contemporary cognitive neuroscience research suggests that it is difficult to shift the point of gaze without shifting attention and that both processes involve some of the same neuronal "machinery" (Henderson, 2003). Finally, Eysenck *et al*. (2007) suggest that direct measures of attention, such as gaze indices, should be adopted in order to better understand the influence of anxiety on attention control. Therefore, adopting such methods may help to explain what visual behaviors contribute to superior sporting performance and may also provide a mechanistic account of why performance is sometimes disrupted under the pressures of competitive sport.

In soccer penalty shootouts, anxiety has been shown to be *the* major contributing factor to influence performance failure (Jordet *et al*. 2007). In a series of recent studies possible mechanisms behind these anxiety-induced performance disruptions have been identified using gaze registration technology. Wood and Wilson (2010a) attempted to explore the implications of dissociating gaze and aiming intention in penalty kicks. Results revealed that looking centrally (at the goalkeeper) caused penalties to be hit more centrally, despite participants striving to hit distal areas of the goal. Conversely, more accurate shooting was achieved when participants aligned gaze with aiming

110

intention. The authors discussed these results as being supportive of a tight coupling existing between gaze, and the visuomotor control of aiming actions; with target information from the gaze system being used to guide the output from the motor system (see Land, 2009).

Wilson *et al.* have also previously demonstrated that anxiety can disrupt this goal-driven attentional control in penalty taking. Wilson *et al.* (2009) reported disruptions to both gaze behavior and performance in football players asked to take penalties under threatening conditions. The results indicated that when anxious, participants demonstrated an attentional bias towards the centrally positioned goalkeeper. This anxiety-induced change in gaze location seemed to influence shot direction, leading to more centrally hit kicks and more saved shots. In a further study, Wood and Wilson (2010b) manipulated the saliency of the goalkeeper by asking him to attempt to distract the penalty taker (by waving his arms) under counterbalanced conditions of threat. Results suggested that participants were more distracted by a moving goalkeeper than a stationary one and struggled to disengage gaze from a moving goalkeeper under situations of high threat. Significantly more penalties were saved when the goalkeeper was distracting and shots were also hit closer to the goalkeeper on these trials.

Both Wilson *et al.* (2009) and Wood and Wilson (2010b) concluded that this shift in attentional control, towards the 'threatening' and distracting goalkeeper, was supportive of the predictions of attentional control theory (ACT; Eysenck *et al.* 2007). ACT predicts that under high threat conditions participants display an attentional bias towards threat-related distracting stimuli. Due to the tight link between gaze and subsequent motor actions (Land, 2009) more centralized shots resulted from this anxiety-induced centralized gaze. In short these studies highlight that anxiety induces

sub-optimal, stimulus-driven attentional control that is detrimental to shooting accuracy. However, Wood and Wilson (2010b) found that this effect was more pronounced during the aiming phase (prior to the run-up) than the execution phase (during the run-up) of a penalty kick. It appears that the gaze behavior prior to the run-up is essential in producing accurate shots and it is this gaze that is susceptible to disruption when anxious. Therefore, if performance disruption in this task is attributable to sub-optimal visual attentional control then it may be possible to train optimal attentional control for accurate penalty shooting.

It is widely accepted that for far aiming (targeting) skills, optimal attentional control centers on 'where and when to focus' in the period preceding the critical movement (Vickers 2007). The location and timing of this final fixation (the quiet-eye (QE); Vickers 1996) has been shown to robustly characterize expertise across a wide range of tasks (see Mann *et al.* 2007; Vickers 2007 for reviews). Furthermore, this gaze strategy has been shown to be trainable for both novice (Vine and Wilson 2010; in press) and experienced (Causer *et al.* 2011; Harle and Vickers 2001; Vine *et al.* 2011) performers and for a range of far aiming sport skills. These studies have demonstrated that training a QE fixation may have benefits for performing under pressure and in real competition. So, where are the critical locations and when is the crucial period for effective attentional control underpinning accurate shooting in soccer penalty kicks?

The findings of Wood and Wilson (2010b) not only highlighted how anxiety affects performance in penalty shooting but also shed light on the gaze behavior behind successful and accurate shooting. Specifically, this research suggested that information from the aiming phase of the penalty kick (before the initiation of the run-up) has an overriding influence on subsequent shot accuracy, with centralized gaze producing more centralized shooting. However, this target-related information needs to be stored for the

duration of the run-up, so it can be applied at the point of contact to direct the ball towards the intended target (cf. Hayhoe *et al*. 2003). Wood and Wilson suggested that by focusing almost exclusively on the ball during the run-up, penalty takers safeguard these prior aiming commands and prevent their disruption.

The aim of this study was to therefore incorporate this knowledge into a QE training regime and to test its utility for optimizing the visual attentional control and performance of penalty takers under pressure. This is the first study that has attempted to train the visual attention of soccer penalty takers and it was hypothesized that participants who received QE training would display better shooting accuracy than placebo participants during a retention test designed to assess the efficacy of the training interventions (cf. Harle and Vickers 2001; Vine and Wilson 2010; Vine *et al*. 2011). This is also the first study to re-create a representative penalty shootout in an effort to test the intervention's robustness under competitive pressure. While, previous laboratory studies examining the effect of attentional manipulations on penalty success have adopted multiple-kick designs (Binsch *et al*. 2010; Wilson *et al*. 2009; Wood and Wilson 2010a,b), in reality soccer players only get one shot. It was hypothesized that the QE trained group would maintain target-focused, goal-driven attentional control under the pressure of a penalty shoot-out, and thus maintain performance (as Vine and Wilson 2010, in press; Vine *et al*. 2011). However, the placebo group participants' attentional control was expected to be more disrupted under pressure, resulting in significantly poorer performance (as Wilson *et al*. 2009; Wood and Wilson 2010b).

Methods

Participants

Twenty university level soccer players of the same competitive level were randomly split into two groups. Based on the effect size evident of performance

improvement for QE training in Harle and Vickers' (2001) study (0.92), G*power predicts a total sample size of 12 would give sufficient power (0.80) to detect a significant difference at the alpha level of .05. There was no significant difference between the age ($p = .66$) of the Placebo (mean = 20.3 years, SD = 1.16) and QE group (mean = 20.0 years, SD = 1.25) or their competitive playing experience ($p = .38$; Placebo: mean = 9.6 years, SD = 3.41; QE: mean = 10.9 years, SD = 3.03). There was also no significant difference ($p = .62$) between the self-reported penalty kicking ability of the Placebo (mean = 6.0 out of 10, SD = 1.49) and QE group (mean = 6.4 out of 10, SD = 1.65). Written consent was obtained from all participants and a local ethics committee approved the study before the commencement of any procedures.

Apparatus

A standard, full sized (7.32m wide x 2.44 m wide), soccer goal was marked on a wall and participants shot penalty kicks from the standard distance of 11 meters from its centre. The goal was split into 12 x 4, 61cm squares to aid the rating of shooting accuracy. Similar methods have been used in other studies that have attempted to map the destination of shots in penalty kicks (e.g., Bakker *et al* 2006; Bar-Eli and Azar 2009; Wood and Wilson 2010a and b; Wilson *et al* 2009). The goal area was covered with gym mats (32mm) to prevent injury to the goalkeeper when repeatedly diving on the floor and a standard size 5 Mitre 'Tactic' soccer ball was used in all trials.

Participants were fitted with an Applied Science Laboratories (ASL; Bedford, MA) Mobile Eye gaze registration system that measures eye-line of gaze at 25Hz with respect to eye and scene cameras mounted on a pair of glasses. The system consists of a recording device (a modified DVCR) worn in a pouch around the waist and a laptop (Dell inspiron6400) with 'Eyevision' software installed. A circular cursor, representing 1° of visual angle with a 4.5-mm lens, indicating the location of gaze in a video image

of the scene (spatial accuracy of $\pm$ 0.5° visual angle; 0.1° precision) was recorded for offline analysis. This system was calibrated for each participant using a firewire cable connected to the laptop. When calibrated, the firewire cable was removed allowing the eye tracker, and participant, to be fully mobile. Data were saved to DV tape on the DVCR and subsequently downloaded to the laptop for offline analysis.

Training Groups

As all the participants were of the same competitive level they were randomly allocated to either a Placebo or a QE group at the outset of the study. The Placebo group participants were told that the research was exploring the assumption that practicing penalty kicks would improve performance. They were informed of the optimal scoring areas of the goal (the top corners), and during each training session they were directed to try to score as many kicks as possible past the goalkeeper.

The QE program attempted to teach the participants to maintain focus on an area of the goal offering the best chance of success (i.e. each top corner; Bar-Eli and Azar 2009) prior to the run up. To train this, two targets (1.2m x 1.2m) were displayed within each top corner of the goal and participants practiced shooting to these targets with a goalkeeper present. The targets were numbered 1 and 2 and the performers were required to fixate on either of these, call out the corresponding number (e.g., "number 1") and then focus solely on the ball during the run-up (i.e., the execution phase; Wilson *et al*, 2010b). This verbalization allowed the researchers to ensure the routine was being followed and also allowed the performer to fixate for an appropriate duration (approximately one second) ensuring sufficient pre-programming of force and direction variables (cf. Harle and Vickers 2001; Vickers 1996).

In addition, modeling, video feedback and questioning techniques were incorporated in the training program (Vickers 2007). Specifically, during the first week

of QE training, participants were shown a video of the gaze behavior of a penalty taker using this routine. The participant's own gaze behavior was then compared to this expert model and any differences between the two noted. The first author also reiterated the scientific implications of not aligning gaze with aiming intention. This procedure was followed each week except that in subsequent weeks the individual's gaze video from the previous week's performance was used as the model. In addition to this, questioning techniques were used so that each participant was accomplished at analyzing his visuomotor control and able to identify ways that his performance and attentional control could be optimized further. During the last week of training the QE group were no longer required to verbalize the cognitive trigger (the target number), but to repeat this in their head before shooting. In the hope of increasing their adherence to the QE routine they were told that analysis of their gaze video would identify whether they had adhered to the training instructions.

Testing Period

Testing was carried out over seven consecutive weeks. During week one (baseline) each participant took five penalty kicks with a goalkeeper present while wearing a gaze registration system. This allowed baseline measures of attentional control and shooting accuracy to be observed to which subsequent training induced changes could be compared. The training period consisted of three consecutive weeks (weeks two, three and four) of sessions where participants took one block of 10 penalties to the same goalkeeper. The participants completed a retention test in week five, consisting of five penalties to the same goalkeeper who had been present during the training phase. After a rest week, a transfer test (a penalty shoot-out) was performed in week seven using an experienced goalkeeper who was blind to the status of the players taking penalties.

Measures

Cognitive state anxiety. The cognitive subscale from the Mental Readiness Form-3 (MRF-3; Krane 1994) was used to measure cognitive state anxiety. This scale is anchored between ''worried - not worried'' and was selected as it is a short, expedient inventory that has been employed in other studies that have explored cognitive anxiety's impact on penalty kicking performance (e.g., Wilson *et al*. 2009).

Shooting accuracy. Accuracy was measured by giving each shot an (x) coordinate in relation to where on the goal the ball hit (cf. Wilson *et al*. 2009; Wood and Wilson 2010a,b). Each half of the goal consisted of 6 zones of 61 cm, starting from an 'origin' in the centre (0 cm) and moving out to 366 cm at each post. Therefore higher scores reflected shots that were placed further from the goalkeeper's reach. The coordinate was determined via frame-by-frame analysis of the eye-tracker video file using GazeTracker analysis software (Eye Response Technologies, VA, USA) with a precision of 5 cm (approximately, one quarter the diameter of the ball). Shots that were saved were given an estimated accuracy score reflecting where they were predicted to hit on the goal area. Shots that missed the target were not given an accuracy score. Estimates of shooting accuracy from a sample of 72 shots (14 saves and 58 goals) revealed an inter-rater reliability of 96.2%.

Success rate. A measure of performance outcome was attained by tallying the number of shots, (1) which were successful (i.e. scored); (2) which missed the target completely; and (3) which were saved by the goalkeeper.

Attentional control. Two measures of attentional control were assessed for both phases of the penalty kick as first outlined by Wood and Wilson (2010b). The aiming phase began when the player first fixated on the goal area after placing the ball on the penalty spot and ended when the player initiated the first step of his run-up. The

117

execution phase started on this first step and ended on foot-to-ball contact. A quiet eye (QE) analysis was carried out for both the aiming and execution phases of the kick.

During the aiming phase the location of the last fixation, prior to the initiation of the run-up, was given an x and y coordinate (using the same methods as shooting accuracy; Wilson *et al*. 2009; Wood and Wilson 2010a,b). The duration of this fixation (A-QE) was also determined in the Gazetracker software environment. Previous research has shown that during the run-up, soccer players predominantly fixate on the ball (Wood and Wilson, 2010b). Such gaze behavior is typical in abstract aiming tasks (e.g., golf putting and ice hockey shooting), where the object to be struck is the target of the quiet-eye fixation (Vickers, 2007). Therefore, during the execution phase the duration of the last fixation on the ball (B-QE) was analyzed with respect to the backswing of the kicking leg (final movement) using Quiet Eye Solutions software (www.QuietEyeSolutions.com). A second trained observer, blind to the status of each player, re-analyzed 86 shots. Inter-rater reliability was 97.7% for A-QE and 96.9% for B-QE.

Procedure

In the baseline and retention test conditions (weeks 1 and 5) all participants attended individually. The eye-tracker was calibrated by asking each participant to direct his gaze to six points marked on the goal. Each participant then completed the MRF-3 and took five shots with the goalkeeper present. Before all kicks participants stood on the penalty spot, ball in hand and a quick calibration check was performed. During the training period (weeks 2-4) the placebo group participants took 5 familiarization penalty kicks, were calibrated to the eye tracker and completed the MRF-3. The QE group participants followed the same procedure after completing their modeling, video feedback and questioning session. Each group then took ten kicks

using their differing experimental instructions with calibration checks carried out before each kick.

Following a rest period in week 6, all participants met at the testing environment in week 7 and competed in a 'live' penalty shootout, where each participant took only one kick. The two teams were given different color bibs and were segregated from each other on facing team benches. Participants were introduced to the goalkeeper, who was different from the one used throughout training. It was emphasized that he played at a high standard, had extensive penalty kick experience and was considered a penalty saving specialist. Both teams were made aware of a £100 cash prize for the winning team, and were informed of the rules of the shootout. A researcher then tossed a coin to determine which team would shoot first.

The order in which participants were selected to come forward from each team was determined randomly prior to the shootout. The identity of the next penalty taker for each team was only divulged to the group once the prior penalty had been taken. This strategy was used to manipulate anxiety by increasing the level of uncertainty experienced. Two identical ASL Mobile Eye gaze registration systems, one for each team, were used to expedite the testing process. Once called forward, each participant was calibrated to the eye-tracker, completed the MRF-3 and took his penalty kick. At the end of the shootout, participants were debriefed about the aims of the study.

In an effort to increase the threatening nature of the goalkeeper he wore a red goalkeeper top (Hill and Barton 2005). He was told to behave as he would do in a competitive shootout and to try and save as many shots as he could. The goalkeeper was paid £20 for attending and was told he would receive an additional £1 for every save he made. This was incorporated so that the effort of the goalkeeper was maintained throughout the shootout.

Data Analysis

In order to monitor the effectiveness of the QE program in training effective visuomotor control, shooting accuracy data were analyzed across the five weeks of the training period (from baseline to retention) with a mixed design 2 x 5 ANOVA (group x week). Success rate was analyzed using a mixed design 2 x 3 x 5 MANOVA (group x outcome: goal, save, miss x week). The location and duration of last aiming fixation (A-QE); and duration of last ball fixation (B-QE) data were subjected to mixed design 2x2 ANOVAs (group x week: baseline, retention).

In order to assess the effectiveness of the 'shootout' anxiety manipulation a mixed design 2 x 3 ANOVA (group x week) was performed on the MRF-3 data across baseline, retention and penalty shootout weeks. Finally, a series of 2 x 2 mixed design ANOVAs were used to compare shooting accuracy, location and duration of last aiming fixation (A-QE) and duration of last ball fixation (B-QE) for each participant's first kick during the retention week to the kick in the shootout. Using the first kick of the retention test in this way provided a single-trial, baseline measurement from which we could explore anxiety's effect on attentional control and performance under pressure. Where sphericity was violated Greenhouse-Geisser corrections were applied. All relevant interactions and main effects were followed up using Bonferroni corrected paired samples *t*-tests and effect sizes were calculated using Partial Eta squared (η_p^2).

Results

Performance: Training

Shooting accuracy. A significant main effect was found for group $F(1,9) = 15.75$, $p < .01$, $\eta_p^2 = .64$, with the QE trained group shooting further away from the goalkeeper (mean = 264.57cm, $SD = 26.09$) than the Placebo group (mean = 218.76cm, $SD = 39.05$). No significant main effect was evident for week, $F(4,36) = 1.48$, $p = .23$,

but a significant interaction effect was evident, $F(4,36) = 2.90$, $p < .05$, $\eta_p^2 = .24$. Post hoc tests revealed that while there was no significant difference between groups pre-training ($p = .70$), the QE trained group shot significantly further away from the goalkeeper than the placebo group after week 2 ($p < .05$) and maintained this advantage throughout training and the retention test (all p's < .01; Figure 12).
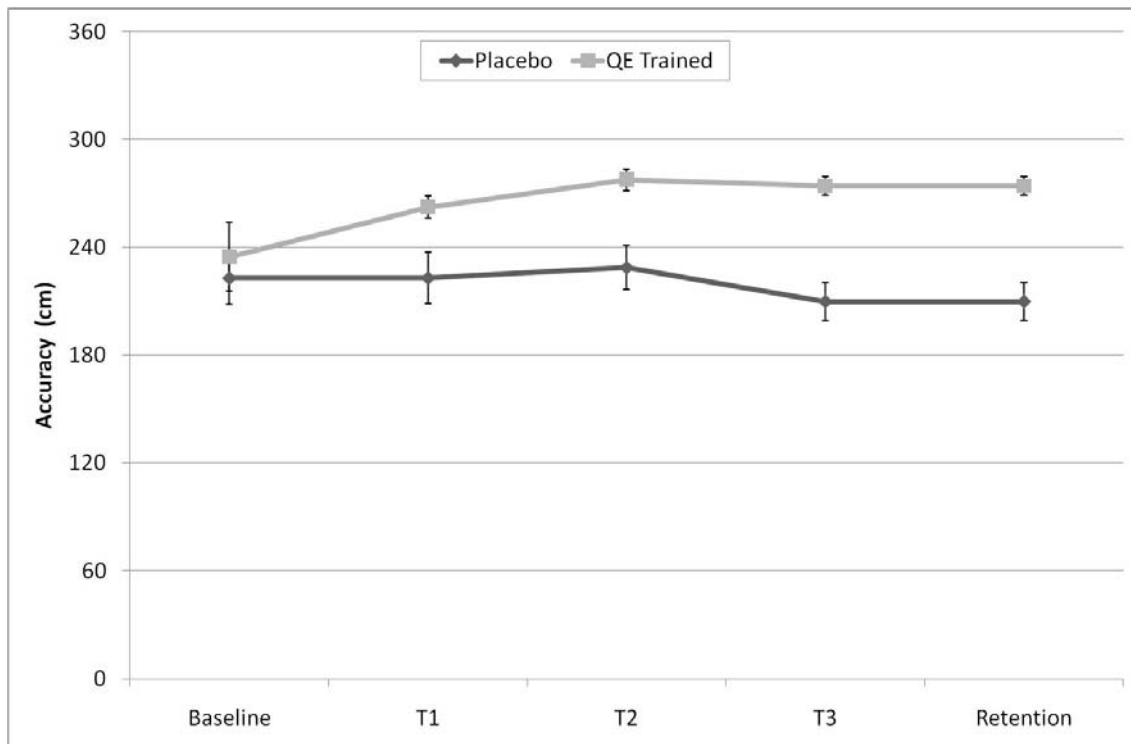
Figure 12. Shooting accuracy (mean displacement of shot location from goal center) for QE and Placebo groups in baseline, training, retention weeks (with s.e.m.s)

Success rate. MANOVA revealed a significant three-way interaction, Wilk's $\lambda = .12$, $F(1,18) = 5.57$, $p < .05$, $\eta_p^2 = .88$, which was followed up with a series of 2 x 5 ANOVAs for each outcome (goal, save, miss).

Success rate: Goals. For goals scored, there was a significant main effect for week, $F(1.53,13.76) = 4.24$, $p < .05$, $\eta_p^2 = .35$, although post hoc tests revealed no significant differences (all p's > .05) when Bonferonni-corrected pairwise comparisons

were applied. No significant main effect for group and no other significant interaction effects were evident (ps > .05; see Figure 13).

Success rate: Saved shots. A significant main effect was found for the number of shots saved between weeks, $F(4,36) = 13.05$, $p < .001$, $\eta_p^2 = .59$, with less shots being saved, compared to baseline, after two weeks of training regardless of which training was received. A significant main effect was also found for group, $F(1,9) = 6.46$, $p < .05$, $\eta_p^2 = .42$, with the placebo group having more shots saved (14%) compared to the QE group (7%). A significant interaction, $F(4,36) = 3.00$, $p < .05$, $\eta_p^2 = .25$, revealed that the number of shots saved decreased during the first week of QE training and continued to be significantly ($p < .05$) lower throughout the training period. However, this advantage diminished during the retention test ($p = 1.00$; see Figure 13).

Success rate: Missed shots. No significant main effects or interactions were evident for the number of shots that missed the target completely (ps > .05; see Figure 13).
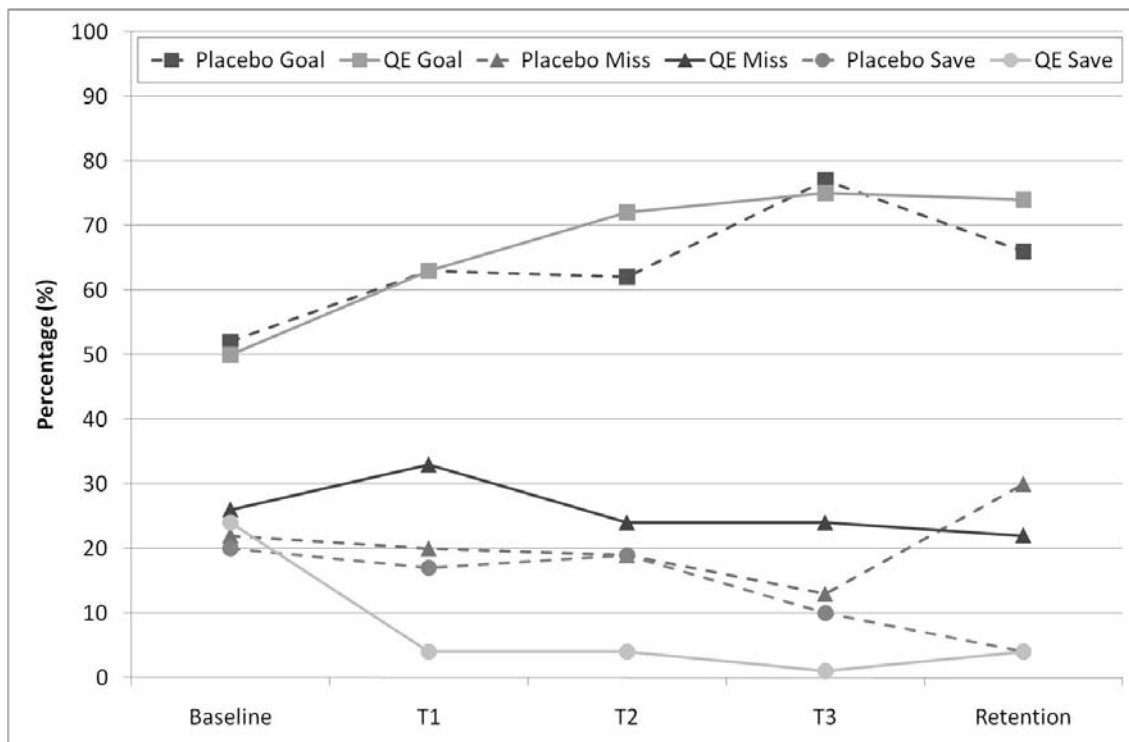
Figure 13. The percentage of shots that scored, missed the target completely, or were saved in baseline, training and retention weeks.

Attentional Control: Aiming Phase

Location of last fixation. No significant main effect was found for the location of last fixation between groups, $F(1,9) = .58$, $p = .46$, or across weeks, $F(1,9) = 1.08$, $p = .33$. The interaction effect was significant, $F(1,9) = 5.30$, $p < .05$, $\eta_p^2 = .37$, with no significant difference between the location of last fixation evident prior to training ($p = .53$) but with the QE group having significantly more distal final fixations ($p < .05$) after the training period (Table 2).

Table 2. Mean (and standard deviation) of location of last fixation (cm) and Quiet Eye fixation duration (ms) for the aiming (A-QE) and execution (B-QE) phase of the penalty kick for each group at baseline and retention weeks.

	Location of Last Fixation		A-QE		B-QE	
	Baseline	**Retention**	**Baseline**	**Retention**	**Baseline**	**Retention**
Placebo	249.86	238.80	245.00	301.46	507.20	434.98
	(45.04)	(55.11)	(59.17)	(109.25)	(606.55)	(386.27)
QE Trained	229.75	290.80*	260.63	902.93**	422.60	706.55**
	(102.77)	(20.09)	(26.47)	(355.43)	(226.40)	(192.04)

*$p < .05$, ** $p < .01$

Duration of last fixation (A-QE). A significant main effect was found for group, $F(1,9) = 22.80$, $p < .01$, $\eta_p^2 = .72$, with the QE group having longer target-focused, A-QE (mean = 581.78ms, $SD = 190.95$) than the Placebo group (mean = 273.23ms, $SD = 84.21$). A significant main effect was also evident for week, $F(1,9) = 55.66$, $p < .001$, $\eta_p^2 = .86$, with both groups displaying longer A-QE after training (mean = 602.20ms, $SD = 232.34$) compared to before training commenced (mean = 252.82ms, $SD = 42.83$). A significant interaction, $F(1,9) = 18.17$, $p < .01$, $\eta_p^2 = .67$, revealed that the QE group had significantly longer A-QE after training ($p < .01$) compared to the placebo group. No significant differences in A-QE existed prior to the commencement of the training period ($p = .49$; see Table 2).

Attentional Control: Execution Phase

Duration of last fixation (B-QE). Results indicated that there was no significant difference in QE duration on the ball (B-QE) between each group, $F(1,9) = .29$, $p = .60$, or across weeks, $F(1,9) = 2.9$, $p = .12$. However, results revealed a significant interaction between group and week $F(1,9) = 13.25$, $p < .01$, $\eta_p^2 = .60$. Paired sample t-tests revealed that the QE group significantly increased their QE duration on the ball

from baseline to retention test ($p < .001$). No other significant between or within group differences were evident ($ps > .12$; See Table 2).

Penalty Shootout

Cognitive anxiety. A significant main effect for week, $F(1.17,10.48) = 46.71$, $p < .001$, $\eta_p^2 = .84$, revealed that participants reported significantly higher cognitive anxiety levels during the shootout (mean = 5.05, $SD = 1.97$) compared to baseline (mean = 2.50, $SD = 0.78$) and retention (mean = 2.20, $SD = 1.10$) conditions ($ps < .01$). No significant main effect was evident for group, $F(1,9) = 1.22$, $p = .30$, and the interaction effect was non-significant, $F(1.17,10.48) = .69$, $p = .51$.

Shooting accuracy. Analysis of the shooting accuracy scores from the first kick of the retention test compared to the kick in the shootout revealed no significant differences between groups, $F(1,6) = 1.27$, $p = .30$; across test weeks, $F(1,6) = 0.59$, $p = .40$; nor a significant interaction, $F(1,6) = 2.96$, $p = .14$ (see Table 3). The QE group won the penalty shootout scoring eight goals, missing the target once and having one shot saved. The placebo group scored seven goals, missing the target on three occasions.

Attentional control. A significant interaction effect for the location of last fixation, $F(1,8) = 18.91$, $p < .01$, $\eta_p^2 = .70$, revealed that the placebo group adopted significantly more centralized fixations under pressure compared to at retention ($p < .05$) and compared to the QE group under pressure ($p < .01$). The QE group maintained distal aiming fixations in both conditions ($p = .45$; see Table 3). A significant main effect for group, $F(1,8) = 18.66$, $p < .01$, $\eta_p^2 = .68$, was found for the duration of this last aiming fixation (A-QE) with QE trained participants displaying longer aiming fixations on the goal compared to the placebo group (Table 3). No significant main effect for week, $F(1,8) = 1.03$, $p = .34$, and no significant interaction was evident, $F(1,8)$

125

= 0.17, p = .69 for the A-QE data. No significant differences were found for B-QE

between groups, $F(1,9) = 1.11$, p = .32; across weeks, $F(1,9) = 0.07$, p = .80, and the

interaction was also non-significant, $F(1,9) = 1.80$, p = .21 (Table 3).

Table 3. Mean (and standard deviation) of shooting accuracy, location of last fixation (cm) and Quiet Eye fixation duration (ms) for the aiming (A-QE) and execution (B-QE) phase of the penalty kick during the first kick of retention and penalty shootout.

	Shooting Accuracy		Location of Last Fixation		A-QE		B-QE	
	Retention	**Shootout**	**Retention**	**Shootout**	**Retention**	**Shootout**	**Retention**	**Shootout**
Placebo	182.85 (97.59)	242.85 (42.85)	220.77 (79.22)	104.44** (122.89)	278.83 (101.57)	242.00 (182.73)	426.83 (355.59)	511.00 (709.02)
QE Trained	259.29 (51.03)	244.29 (89.23)	295.56 (26.51)	308.33 (46.50)	674.03 (374.88)	562.70 (383.08)	711.65 (206.59)	575.80 (239.16)

Discussion

This is the first study to date that has attempted to train the visual attention of soccer players for performance success in penalty shootouts. The aim of this study was to explore if, by aligning gaze with aiming intention, penalty takers could increase their shooting accuracy and then maintain this under pressure. While other aspects of the penalty shootout scenario are outside the kicker's control, penalties that are struck to the corners of the goal are more likely to score, irrespective of the behaviors and ability of the goalkeeper (Bar-Eli and Azar 2009). The QE training therefore focused on helping the performer maintain control over key components of his visual attention and visuomotor coordination prior to and during the kick. Specifically, this strategy involved maintaining a long final aiming fixation (A-QE) to a distal target prior to initiating the run-up, and then maintaining a ball focused fixation (B-QE) during the strides leading up to the initiation of the kicking action. It was hoped that such training would (a) teach players effective visuomotor control for the task, and (b) provide them with a strategy to follow to maintain optimal visuomotor control and subsequent performance under the pressure of a competitive penalty shootout.

Training Effects

The QE routine was successful in differentially improving shooting accuracy over the training period, when compared to a placebo group (see Figure 12). By week 3 of training there were 50cm differences in the horizontal shot placement of both groups, with the QE trained group's shots being placed effectively three ball diameters further away from the goalkeeper's starting position. As there were no differences in shot placement prior to training, this difference is most likely reflective of the effectiveness of the training provided.

However, there may be alternative explanations for these accuracy effects, related to the training instructions provided to the placebo group. Although they were informed that the corners were the optimal scoring locations, they were not explicitly told to practice kicking to these locations (cf. the QE group). It is possible therefore that the group performance differences are due to the placebo participants simply having less practice at kicking to distal areas of the goal, or consciously deciding not to adopt this strategy. Instead these participants may have fixated on the goalkeeper in order to determine which side he would dive to and then shot to the other side of the goal – reducing the accuracy needed to be successful. However, the final aiming fixation data (Table 2; Retention) suggests that these participants were fixating, and presumably aiming, towards the outside third of the goal and not the goalkeeper. Further research may wish to alleviate this limitation by directing players to hit target areas through instructions that do not influence aiming behaviour (e.g. put the ball beyond the goalkeeper's reach) with those that do (QE training). Such a procedure was not followed in this study as we wished to explore any changes to aiming and performance through non-guided practice, which is typical in professional preparation for such scenarios.

While group differences in shooting accuracy did not transcend to significant differences in the number of shots scored or missed, the greater accuracy displayed by the QE trained participants resulted in significantly fewer (50%) shots being saved during the training period (Figure 13). This difference in saved shots was not evident during the retention test, perhaps due to the large increase in the number of missed shots by the placebo group during retention. Why this happened is quite perplexing as both groups seemed relatively stable in their success rates before this point (Figure 13). One explanation may be that the placebo participants decided, either consciously or unconsciously, that they would vary their kicking strategies during this test week in order to keep the goalkeeper guessing as to how they approached each shot and which

direction they shot to. Such behavior is typical in penalty takers forced to take multiple kicks (Wood and Wilson, 2010a) and this effect may have built momentum during repeated weeks of shooting to the same goalkeeper. Nonetheless, the overall effect of the QE training regime was to make resultant shots more accurate, further from the goalkeeper's reach and less likely to be saved.

As predicted, the performance accuracy effects evident following training were underpinned by fundamental differences in gaze behavior during the aiming phase of the kick. The QE group learned to display more distal final aiming fixations (Table 2) and maintained these fixations for approximately three times as long as their placebo group counterparts (Table 2). Harle and Vickers (2001) have previously demonstrated that training a longer aiming fixation to the front of the hoop in basketball free throw shooting improves the free throw percentage of experienced performers. The results of the current study further demonstrate that improvements in already stable (experienced) visuomotor performance can be crafted via changes in visual attentional control (cf. Causer *et al*. 2011; Vine *et al*. 2011).

The mechanisms behind this change in performance may be explained in relation to Land's (2009) conceptualization of several distinct but interacting brain systems involved in the visual control of action. Land suggests that the *temporal* and *spatial* relationships between gaze fixations and the action they facilitate reflect how top-down schema instructions are executed. Therefore, by focusing on the desired location (inside the post), the gaze system can forward information to the motor system, guiding the coordination of the requisite motor plans for the successful completion of the kick (Wood and Wilson 2010b). Furthermore, longer quiet eye periods may also permit an extended duration of programming of these target parameters, while minimizing possible distractions from irrelevant environmental cues (cf. Vickers 1996).

Interestingly, after training the QE group also increased their final fixation on the ball prior to initiating the kicking action (B-QE) compared to the Placebo group (Table 2). An extended ball-focused QE has been shown to underpin successful performance in other tasks requiring the striking of a ball towards a distal target (e.g., golf; Vickers 1992). By focusing on the part of the ball to be struck, an accurate contact is more likely, thereby increasing consistency and accuracy (Wilson and Pearcey 2009). An additional complexity of the soccer penalty however, is that the kicker cannot explicitly align the ball to the target in advance as in golf putting. Instead, aiming intention must be transformed into direction and force parameters for ball contact during the run-up. We suggest that the B-QE aids the process of transformation of visual information from the aiming phase into motor output and guides these parameters for accurate foot-to-ball contact (Wood and Wilson 2010b).

Pressure Effects: Shootout

The purpose of the shootout was to manipulate the anxiety experienced by the participants and also to test the robustness of the QE training strategy under constraints more representative of competitive soccer. The analysis of the MRF-3 data revealed that both groups were significantly more anxious in the shoot-out than in the baseline or retention tests, thus supporting the validity of the manipulation. It is acknowledged that the intensity of the anxiety is certainly less than that experienced in competitive environments where consequences of poor performance are greater (Jordet *et al*. 2007). However, it is worth noting that even at the levels of anxiety reported in the current study, and those like it (e.g., Wilson *et al*. 2009; Wood and Wilson 2010b), significant detrimental effects on attentional control and penalty performance have been uncovered.

It was predicted that the attentional control of the Placebo group would be most impaired by the shootout as they had not been taught a strategy to maintain effective

gaze control. Support for this hypothesis was found with QE participants maintaining more distal aiming fixations compared to the Placebo group who showed impaired centralized gaze (Table 3). Wilson *et al*. (2009) discussed a similar impairment in attentional control in relation to the predictions of attentional control theory (ACT; Eysenck *et al*. 2007). As the sole source of external threat in the immediate environment, the goalkeeper is likely to attract the kicker's visual attention, thus preventing accurate, distal aiming fixations (cf. Wood and Wilson 2010b). The centralizing of gaze may also be explained by Easterbrook's (1959) cue utilization hypothesis, which suggests that increased arousal narrows attention, restricting the range of incidental cues that are used.

The shooting accuracy results for the penalty shootout provide only partial support for our initial hypotheses however, as the placebo group's performance was not significantly impaired. The QE group's data is supportive of the effectiveness of the training, as they were able to maintain their retention test accuracy under the pressure of the shootout (Table 3). However, the placebo group was also able to maintain shooting accuracy, despite the significant centralizing of gaze (Table 3). While it is clearly possible to dissociate gaze from performance, as the placebo group may have done in the shootout, a large body of research, using many trials, now exists that has repeatedly shown that such a dissociation has negative effects on shooting accuracy in this task (Bakker *et al*. 2006; Binsch *et al*. 2010; Wood and Wilson 2010a and b; Wilson *et al*. 2009) and is also contrary to fundamental research in visuomotor control (Land, 2009). Therefore the adoption of such an approach is strongly discouraged for long term gains in shooting accuracy and performance success in penalty kicks.

The lack of support for our hypotheses for the shootout may be attributable to the adoption of a single shot design. As there are only a maximum of 20 data points for

each dependent variable in the shootout, this unexpected result for shooting accuracy may be driven more by high individual variability rather than any influence of the pressure manipulation. We have previously revealed attentional and subsequent performance disruptions using more traditional multiple-kick pressure conditions (Wilson *et al*. 2009; Wood and Wilson 2010b). However, we have also revealed that kickers in these types of manipulations are likely to artificially vary their kicking strategies to prevent the goalkeeper from learning their preferences (Wood and Wilson 2010a). Therefore adopting such a design in this study would have increased the likelihood that the QE training regime would have been abandoned. We therefore wanted to engineer a situation where the penalty taker would adopt what he felt to be his optimal strategy for success in a one-off attempt, typical of real shootouts. Future research should possibly introduce a multiple-kick stress manipulation (as Wilson *et al*. 2009) before recreating a penalty shootout scenario in order to provide a more rigorous test of the link between gaze and shooting accuracy under pressure. However, we still feel that the introduction of a single kick design offers ecological insight into the manner in which anxiety affects the processes (attentional control) behind performance disruption in highly pressurized, one-off instances that are typical in sport (cf. Woodman and Davis 2008).

Despite these limitations in research design, the QE group did improve performance (retention test) and maintain it under pressure (shootout), despite the number of practice trials in the current study (30 penalty kicks over 3 weeks) being lower than those typically adopted (Causer *et al*. 2011; Harle and Vickers 2001; Vine and Wilson 2010). It may be that for experienced performers a large part of the intervention's success might lie in simply educating them that they should maintain this focus under pressure; therefore, long periods of training may not be necessary. In support of this contention, Vine *et al* (2011) have recently demonstrated the benefits of

even a single, brief QE training session for skilled golfers; with QE trained golfers putting more accurately than a placebo group in both a laboratory-based pressure test and over ten subsequent rounds of golf. Further research activity is required to further our understanding of *how* QE training impacts upon performance under pressure (see Vine *et al*. 2011), as such findings might influence the content and duration of subsequent interventions for aiming tasks.

While caution needs to be taken in applying the results of this study to the development of a definitive penalty QE-training program, there may be implications for training the penalty shot. By aligning gaze with aiming intention, players are more likely to accurately hit distal regions of the goal. Although the degree of accuracy and precision required may be less than for tasks like putting (the kicker only has to beat the goalkeeper), this strategy also removes the uncertainty associated with waiting to respond to the goalkeeper's anticipatory movements. Uncertainty is one of the key antecedents associated with anxiety (Lox 1992), so any strategy that increases perceived control should be beneficial in competitive, pressurized settings. As goalkeepers do not appear to utilize information from the kicker's eyes, it is also unlikely that advanced anticipatory cues are being provided (Dicks *et al* 2010; Savelsbergh *et al* 2005). We suggest that performers should therefore treat the penalty as a far-aiming task, and practice hitting the optimal scoring regions (the top corners) with sufficient power to beat a goalkeeper (Bar-Eli and Azar, 2009).

To conclude, the results of the current study suggest that the visual attentional control of a penalty taker before the run-up begins is important for subsequent shooting accuracy. The QE intervention successfully helped experienced participants to direct their visual attention optimally prior to and during the penalty kick; first aligning gaze with aiming intention and then guiding accurate foot-to-ball contact. It was noteworthy that this

strategy underpinned changes in performance above those of a Placebo group after only two weeks of training, and was robust under the pressure of a shootout manipulation. Future research is warranted to further our understanding of the separate and cumulative role of aiming and execution fixations in penalty kicks; the effect of pressure on the visuomotor planning and control of the skill; and the utility of brief gaze-based training interventions for experienced sports performers in general.

Chapter 6: Summary, Implications and Conclusions

Summary and Practical Implications

The aim of this series of studies was to explore the visuomotor control of football penalty takers and how such control may be compromised by anxiety. Specifically at the outset of this research four main research questions were identified and a summary of the conclusions of these studies will now address how each research question has been answered.

The first aim was to establish what represents optimal, top-down attentional control for football penalty takers. In experiment 1 of chapter 2, it was found that footballers were significantly less accurate in their shooting when gaze was constrained centrally. This has important implications for penalty takers as it has been proposed that the majority of penalty kicks are hit whilst the penalty taker fixates and monitors the movements of the centrally positioned goalkeeper (Kuhn, 1988, Wood and Wilson, 2010). Such an approach was associated with shots being hit significantly closer to the goalkeeper increasing the chances of a save occurring. Interestingly, in the same study, but when gaze was not constrained, footballers naturally tended to align gaze with aiming intention. So when participants were asked to hit distal corners of the goal every participant looked to where they were aiming. This is a finding that has been displayed in many of the studies within this manuscript where during warm up shots, with no goalkeeper present, players are constantly observed aligning gaze with aiming intention. It is therefore apparent that players know, either consciously or consciously, that in order to hit an accurate shot they must look to where they want to hit. I propose that this represents top-down attentional control in this task and adopting such an attentional strategy produced significant increases in shooting accuracy.

Additionally, when a goalkeeper was introduced (Experiment 2, Chapter 2) the worst performers predominantly used a KD strategy, whereas the better performers

predominately aligned gaze with aiming intention. This offers further support for a coordinated gaze and aiming strategy being optimal, and a centralised keeper-based strategy being sub-optimal. The message from this primary study is clear: in order to hit an accurate shot penalty takers must look where they are aiming.

Anxiety is reported to negatively affect performance by disrupting goal-directed, top-down attentional control and causing attention to become more stimulus-driven. The results of the second study added strong support for this and the predictions of ACT (Eysenck *et al* 2007). Specifically, when footballers were anxious it seemed that they worried about the actions of the 'threatening' goalkeeper and, as a consequence, fixated on him earlier and for significantly longer periods. Such centralized gaze brought about more centralized shooting as in chapter 2. This was the first study to explore the gaze-based mechanisms behind performance failure in penalty kicks.

In chapter 4, we explored the implications of the previous studies' findings from a goalkeeper's perspective to explore how a goalkeeper may use this information in successful penalty shot defence. ACT predicts that anxious performers become easily distracted particularly if the distracter is threat-related. Therefore we predicted that if the salience level of the goalkeeper was increased (by actively trying to distract the penalty taker) then the attentional disruptions witnessed in chapter 3 may be increased and performance would become less accurate as a consequence. Results indicated that when goalkeepers employed distraction techniques they saved 15% more penalty kicks. Such performance disruption was again underpinned by fundamental anxiety-induced changes in attentional control. Specifically, during the aiming phase of the kick a distracting goalkeeper increased the total amount of time the participants spent fixating on the centrally positioned goalkeeper and this disruption produced more centrally hit shots.

The visual attentional control during the execution phase of the kick (during the run-up/approach to the ball) was exploratory in nature. Anecdotally, there are quite a few examples of professional players saying they watch the goalkeeper during the run-up (e.g., Berbatov, 2009). Yet in chapter 4 and 5, the only studies that have explored this aspect of the kick so far, players seem to predominately fixate on the ball. We propose that such visual behaviour has two benefits that ensure shooting success: (1) to guide the player towards the ball thereby ensuring successful and accurate foot-to-ball contact and (2) to safeguard the target focused information from disruption, thereby ensuring that such information in transferred in the formulation of an accurate shot.

In the final study we aimed to teach a gaze-based pre-shot routine that was designed to direct top-down attentional control in order to maintain performance under pressure. Results during the training period indicated that the QE trained group had more effective visual attentional control; were significantly more accurate; and had 50% fewer shots saved by the goalkeeper than the control group. Both groups then competed in a penalty shootout to explore the influence of anxiety on attentional control and shooting accuracy. Under the pressure of the shootout the QE trained group failed to maintain their accuracy advantage, despite optimizing visual attention, and the control group maintained performance despite poor attentional control. The results therefore provide partial support for the effectiveness of brief QE training interventions for experienced performers under pressure

This series of studies has undoubtedly advanced current knowledge regarding the visuomotor control of penalty taking and the effect that anxiety may have on attentional control and performance in this task. The studies have also shed light on how these findings may be utilised by goalkeepers, and offers some practical considerations to penalty takers in order to enhance their shooting accuracy. Despite this, there is still a

great deal of further research that warrants the attention of psychologist in order to further our understanding of the visuomotor and attentional control of athletes in penalty kicks and aiming skills in general. There is also a lot to learn regarding the attentional disruptions attributable to anxiety in motor task performance and there is still a great deal of enquiry needed to fully test the predictions of ACT in sport. The next section will outline some possible research directions that could guide such enquiry.

Theoretical Implications

Sport psychology is ideally situated to test cognitive psychological theories in real anxiety-inducing environments such as competition. In this thesis I successfully applied the theoretical proposition of attentional control theory (Eysenck *et al*, 2007) to football penalty kicking performance. While previous studies have attempted to use ACT in explaining anxiety's effect on motor performance, such studies have lacked the stringency needed to make their findings any more applicable to ACT than its predecessor PET (Eysenck and Calvo, 1992; as discussed in the introduction).

This is an important distinction as ACT strives to go further than an explanation of impaired processing efficiency to considering the attentional mechanisms behind such impairments (i.e., disruption in inhibition, shifting and updating functions of the central executive). Researchers wishing to test ACT in sports setting need to take this into consideration when designing experiments and when considering what independent variables can be measured to assess disruptions in one or more of these functions. For example, in chapter 3 we used the time to fixate on the goalkeeper as an indicator of disruption to the inhibition function of the central executive. In this way, while the studies within this thesis do not provide a definitive template for future research in this area, they do offer some novel and effective research methods that are worth

consideration in providing more stringent tests of ACT and its postulations in real world environments.

The studies in this thesis show strongly that ACT can be applied to sports tasks. To date, these studies are the most stringent test of this theory that have been applied to sport and may help to aid our understanding of how anxiety affects attentional processes and subsequent motor performance. The understanding of *how* and *why* attention is disrupted is not only important, but necessary and fundamental to sport psychologists striving to alleviate choking under pressure. Not only this, but ACT also provides a useful framework, as evidenced by chapter 4, for explaining the relationship between anxiety, distraction and performance in aiming tasks and sport in general. This study illustrates nicely that the salience of any environmental stimuli must be assessed in order to evaluate its likely impact on sports performance. Such assessments are likely to be useful in guiding possible intervention designed by sport psychologists.

The findings of this thesis also add further support for the efficacy of a quiet-eye period (Vickers, 1992) in aiming skills. However, debate surrounds the possible mechanisms behind why the QE period continually promotes superior performance. In brief, four perspectives exist that have attempted to explain how the QE works. The cognitive neuroscience perspective suggests that during the QE fixation the neural networks required for accurate aiming are being organised. Therefore longer QE periods have been proposed to reflect a critical period of cognitive processing during which the parameters of the movement such as force, direction and velocity are fine-tuned and programmed (Wilson, 2008).

The ecological perspective suggests that the QE facilitates the orientation of the body and arm movements in space, allowing for the execution of movements that are attuned to any present constraints (Vickers, 2007). In this sense longer QE durations

reflect a longer period of information collection, which in turn allow for the self-organisation of movement responses (e.g., Causer *et al*, 2011). The sport psychology perspective suggests that the QE may be a simple way for performers to maintain focus and concentration whilst performing sports skills under pressure (Vickers and Williams, 2007). Using a QE fixation may facilitate performers being 'in the zone', with a lengthy fixation in one location preventing external visual information from distracting the performer and internal distractions (such as worry) from effecting performance effectiveness (Vickers, 2007). The final perspective is the cognitive-physiological perspective which proposes that the QE may have act as an external focus of attention, redirecting attention away from internal processes and task demands thereby safeguarding performance (Vickers and Williams, 2007).

The findings within this thesis, particularly experiment 1 of chapter 2, show some support for the cognitive and/or ecological perspective of how the quiet eye may work. To recap, in this study participants either had their gaze constrained centrally or were allowed to align gaze with aiming intention and look where they wished to hit. When gaze was aligned with aiming intention, participants were significantly more accurate despite having shorter aiming fixations on the goal. These performance differences cannot be explained by the sport psychology or the cognitive-physiological perspective as under both conditions participants maintained focus on the external target whilst completing the task and even superior focus (indexed by longer QE durations) did not equate to superior performance. The only difference that seemed to influence and explain performance effectiveness between conditions was the location of this aiming fixation. It seems that this information was necessary for superior shooting accuracy in this task and this can be explained by both remaining perspectives.

First, the cognitive-neuroscience perspective would say that by looking to where they wished to shoot participants allowed the eyes to provide the motor system with important performance parameters that were necessary for accurate shooting. On the other hand, the ecological perspective would suggest that by simply aligning gaze with aiming intention, implicit self-organisation of the kicking action necessary for accurate shooting was created. It is evident that for a conclusive answer to understanding the mechanisms behind the workings of the QE, further research is need that aims to teases out the differences between each perspective and test each empirically.

Limitations and Future Research Directions

One of the major limitations of this thesis is the relatively small sample size and small number of trials utilised. Whilst, admittedly, the sample sizes used throughout these studies would benefit from being higher, such samples were used due to time constraints, the lengthy analysis process associated with eye-movement data and the availability of adequate space to carry out such experiments. Nevertheless, the numbers in question were enough to elicit significant performance and attentional control disruptions across conditions and between groups. Furthermore, other studies looking at anxiety and attentional control of sports performers have used very similar or even lower sample sizes for within group comparisons (e.g., Adolphe *et al*, 1997) and between group comparisons of training effects (e.g., Harle and Vickers, 2001; Vine and Wilson, 2011).

The limitation of the low number of trials is both typified and explained by looking at the 30 kick training period in Chapter 5, in which a 10-kicks-a-week practice period brought about significant performance differences after only 3 weeks. This is a very low number of 'learning' trials when compared with similar research (e.g., Vine and Wilson, 2010) and I feel there is an important distinction which needs to be

expanded upon here. What needs to be stressed is that this was not a learning study per se. Penalty takers have been shown to successfully use this gaze strategy in chapter 2; and therefore the training in question was designed to encourage them to practice and adopt the correct gaze (and visuomotor) control on subsequent attempts. Hence we felt that a large part of the intervention's success might lie in simply educating experienced footballers that they should maintain this focus under the pressure of the shootout. This brief, and therefore, 'efficient' approach may indicate that the longer acquisition periods, typical in many learning designs, are not needed for experienced performers. More research is obviously needed to examine this important question.

A further limitation is that the studies contained in this thesis predominately concentrated on the location and duration of the last fixation in theoretical accordance with the QE period (Viickers, 1996). It might also be interesting to look at a more detailed analysis of the order and importance of more fixations (not just the last one). If a memory buffer is utilised for aiming tasks of this nature then earlier fixations may be stored for the eventual production of visually guided action. Future research may wish to analyse the order of fixations in order to better understand *when* and *where* aiming information is taken in and processed or held for future use.

Another aspect of the penalty kick that warrants further attention is the run-up. As already discussed, professional players continually indicate that they focus on the goalkeeper during the run-up. Yet the evidence from these studies, and my anecdotal observations of players taking penalty kicks, suggests that this is not the case, with players tending to focus on the ball. Despite this evidence, it is possible that players *do* focus attention on the goalkeeper during the run-up; however, it is proposed that this attention is likely to be covert, as opposed to overt, in nature. Therefore further studies

144

may wish to explore how peripheral vision and visual pivots may be used in this aspect and other aspects of penalty taking.

Visual pivots consist of foveal fixations to a central location, allowing for the use of peripheral attention to detect peripheral stimuli. Visual pivots have three proposed advantages. Firstly, a single fixation (or visual pivot), rather than several saccadic eye movements is more efficient, as saccadic suppression is minimised. Secondly, while the fovea is excellent at determining detail, the peripheral regions of the retina are more efficient at detecting movement. Therefore, if moving stimuli need to be detected, a centrally focused fixation (visual pivot) allows peripheral vision to pick up motion. Thirdly, research has shown that attention can be shifted more quickly when done so covertly rather than overtly (via eye movements; Posner and Raichle, 1994). To date only Williams and Elliot, (1999) and Nagano *et al*., (2006) have investigated the utility of such behaviours in sport. Researchers should further investigate the use of visual pivots in visuomotor control and decision making in a variety of sport tasks so a greater understanding of the utility of such gaze behaviours can be fully uncovered.

Another possible fruitful avenue for research is the role of memory in aiming skills. A model of visually guided movement outlined that the first visible response in visually guided action is usually an eye movement in the direction of the target stimuli after which the important information for action is extracted. This information is then passed to the motor system via a memory buffer where it can be held for a short period of time before it is required to guide a motor response. Such a facility can allow the eyes to look elsewhere, briefly, without interfering with the on-going motor action. In chapter 4 we have found evidence for such a facility in the visuomotor control of penalty takers. Specifically, as a moving goalkeeper impaired attentional control during

the *aiming* phase, and shooting accuracy in a similar direction, then the aiming information must be stored during the execution phase (when gaze is located on the ball) if it is to guide subsequent shooting direction. Such a finding has important implications for visuomotor control and may aid our understanding of anxiety induced performance disruptions.

For example, very little is currently known with regards to the role of memory in aiming tasks where athletes do not look toward target locations during execution (e.g., penalty kicks, golf putting). Studies from cognitive psychology suggest that the memory buffer is finite in nature, meaning that the length of time that target/aiming information can be stored and utilised in the formulation of successful shots is constrained (Pelz and Canosa, 2001). However, as yet there are many unsolved questions regarding the nature and capabilities of buffers (Land and Furneaux, 1997). Specifically, how is information lost from them (does it simply decay over time or is it erased as motor tasks are completed) and how does information from long-term memory combine with new visual information in the production of accurate movement/performance?

The memory buffer may also explain Binsch *et al*.'s (2010) recent suggestion that anxiety and ironic instructions can have similar effects on gaze and aiming behaviour. If the eye movements of performers are directed to sub-optimal locations, either by ironic instructions or anxiety induced attentional biases, then the aiming information provided to, and stored in, the memory buffer prior to shooting can have a negative influence of subsequent performance. Future research may attempt to assess such a faculty using temporal constraints or target occlusion paradigms under situations of competitive pressure.

More research is required to understand the mechanisms of effective visuomotor control and how these may be impaired under pressure for a variety of sport tasks.

While aiming skills are the easiest to assess from a gaze control perspective, other sport skills requiring decision-making would potentially be a useful avenue for enquiry (e.g., Raab and Johnson, 2007). For example, one of the most important skills in sport is the ability to respond quickly and accurately to the changing demands of the competitive environment (i.e., position of ball, teammates and opponents). However, when anxious it is proposed that the shifting of attention necessary for this accurate decision-making process is impaired (ACT; Eysenck *et al*, 2007). Research may then wish to test ACT's prediction in more dynamic situations from the world of sport where inhibition of attention towards threatening stimuli (opponents) and shifting attention between task relevant stimuli (teammates) could be tested more thoroughly. Furthermore, other performance arenas where visuomotor control is required under pressure are also rife for examination. Indeed, the knowledge gained in sport settings has already been applied to military (Janelle and Hatfield, 2008), police (Nieuwenhuys and Oudejans, 2009) and surgical environments (Wilson, McGrath, and Coleman, 2010).

The role of motivation in the anxiety-performance relationship could also be addressed. Recently, some of ACT's authors have re-devised or clarified motivation effects on processing efficiency. According to attentional control theory, high-anxious individuals often use compensatory strategies such as enhanced effort and use of processing resources to achieve a reasonable level of performance effectiveness (Eysenck *et al*, 2007). However, anxiety can also be associated with deficient recruitment of attentional control resources and this is likely in conditions involving low motivation (e.g., undemanding task; lack of task goals) or it can be associated with substantial (but inefficient) recruitment of such resources, which is more likely in conditions involving high motivation (e.g., demanding task; clear task goals; Eysenck and Derakshan, in press). Future research could explore this notion more clearly and elucidate on the circumstances in which each effect is obtained.

Sailer *et al*, (2005) have already highlighted that the learning of a novel skill is reflected in corresponding changes in gaze strategy and visuomotor control of the performer. There is therefore a need for research that attempts to explore the gaze-based adaptations behind skill acquisition. By doing so, psychologists may be able to devise gaze-based training programs, using explicit instruction, that negate the process of trial-and-error learning thereby making the development of visuomotor expertise a more expedient process. Such research could also have far-reaching implications in the measurement of expertise in critical visuomotor skills such as surgery and driving. For example, in the future it may have possible to assess the proficiency of performers using eye-tracking technology as a diagnostic tool. To date, such assessments are based on performance measures, whereas adopting measures of processing efficiency may offer greater insight into assessment of expertise and may also indicate the vulnerability that some performers may face when attentional resources become taxed.

As more research is being generated in the area of visual expertise there is a greater need to design gaze-based interventions that specifically attempt to combat anxiety-induced attentional disruptions in the hope of preventing performance slips. While the effectiveness of such intervention are receiving continual support in the psychology literature most of this research tends to monitor the effectiveness of such interventions in environments that lack ecological validity. More research should attempt to monitor the effectiveness of gaze-based interventions during real world competitive performance in *situ* (e.g., Harle and Vickers, 2001). Only by doing so can the true validity and utility of such interventions be fully assessed.

In conclusion this thesis has drawn upon evidence from visuomotor control, attention and the current literature concerning how anxiety affects the relationship between vision and movement under pressure. The overriding finding of this research

was that shooting accuracy was optimised when vision was aligned with aiming intention. It was also found that this relationship was disrupted by anxiety, with anxious performers showing an attentional bias towards the threatening goalkeeper. This effect was exacerbated by a goalkeeper that actively attempted to distract the taker. In sum, aligning gaze with aiming intention benefits from the theoretical underpinnings of visuomotor control, and top-down attentional processes, in producing accurate movement responses. By adopting such a gaze strategy penalty takers may protect themselves from performance failure under pressure.

References

Abernethy, B. (1990). Expertise, visual search, and information pick-up in squash. *Perception 19*, 63-77.

Adolphe, R.M., Vickers, J.N., and Laplante, G. (1997). The effects of training visual attention on gaze behaviour and accuracy: A pilot study. *International Journal of Sports Vision, 4*, 28-33.

Ansari, T. L., and Derakshan, N. (2010). Anxiety impairs inhibitory control but not volitional action control. *Cognition and Emotion, 24*, 241-254

Armatas, V., Yiannakos, A., Papadopoulou, S., and Galazoulas, C. (2007). Analysis of the set-plays in the 18th football World Cup in Germany [online]. *Physical training*. Available at: http://ejmas.com/pt/2007pt/ptart_galazoulas_0710.html [Accessed 26 November 2008]

Bakker, F.C., Oudejans, R.D., Binsch, O., and Van der Kamp, J. (2006). Penalty shooting and gaze behaviour: Unwanted effects of the wish not to miss. *International Journal of Sport Psychology, 37*, 265-280.

Bar-Eli, M., and Azar, O.H. (2009). Penalty kicks in soccer: an empirical analysis of shooting strategies and goalkeepers' preferences. *Soccer and Society, 10*, 183-191.

Bar-Eli, M., Azar, O.H., Ritov, I., Keidar-Levin, Y., and Schein, G. (2007). Action bias among elite goalkeepers: The case of penalty kicks. *Journal of Economic Psychology, 28*, 606–621.

Bar-Eli, M., and Friedman, Z. (1988). Psychological stress in soccer: The case of penalty kicks. *Soccer Journal, 33*, 49-52

Bar-Haim, Y., Lamy, D., Pergamin, L., Bakermans-Kranenburg, M.J., and van

    IJzendoorn, M.H. (2007). Threat-related attentional bias in anxious and

    nonanxious individuals: A meta-analytic study. *Psychological Bulletin*, *133*, 1–

    24.

Baumeister, R.F. (1984). Choking under pressure: Self-consciousness and paradoxical

    effects of incentives on skillful performance. *Journal of Personality and Social*

    Psychology, 46, 610-620.

Behan, M., and Wilson, M. (2008). State anxiety and visual attention: The role of the

    quiet eye period in aiming to a far target. *Journal of Sports Sciences, 26*, 207–

    215.

Bekkering, H., Adam, J.J., van den Aarssen, A., Kingma, H., and Whiting, H.T. (1995).

    Interference between saccadic eye and goal-directed hand movements.

    Experimental Brain Research, *106*, 475–484.

Berbatov, D. (2009). I let the team down. Retrieved March 16, 2010, from Sky Sports

    website: http://www.skysports.com/story/0,19528,11667_5211477,00.html

Binsch, O., Oudejans, R. R. D., Bakker, F. C., and Savelsbergh, G.J.P. (2009).

    Unwanted effects in aiming actions: The relationship between gaze behavior and

    performance in a golf putting task. *Psychology of Sport and Exercise, 10*, 628-

    635.

Binsch, O., Oudejans, R.R.D., Bakker, F.C., and Savelsbergh, G.J.P. (2010). Ironic

    effects and final target fixation in a penalty shooting task. *Human Movement*

    Science, *29*, 277–288.

Bishop, S.J. (2007). Neurocognitive mechanisms of anxiety: An integrative account.

    Trends in Cognitive Sciences, *11*, 307-316.

Bishop, S. J. (2008). Neural mechanisms underlying selective attention to threat. *Annals of the New York Academy of Sciences, 1129*, 141–152.

Bishop, S. J. (2009). Trait anxiety and impoverished prefrontal control of attention. *Nature Neuroscience*, *12*, 92-98.

Buckolz, E., Prapavessis, H., and Fairs, J. (1988). Advance cues and their use in predicting tennis passing shots. *Canadian Journal of Sport Science, 13*, 20-30.

Calvo, M. G., and Eysenck, M. W. (1996). Phonological working memory and reading in test anxiety. *Memory, 4,* 289-305.

Causer, J, Holmes P. S., Williams, A. M. (2011) Quiet eye training in a visuo-motor control task. *Medcine and Science in Sport Exercise*

Chattington, M., Wilson, M., Ashford, D., Marple-Horvat, D.E. (2007). Eye-steering coordination in natural driving. *Experimental Brain Research*, *180*, 1-14.

Cohen, J. (1988). *Statistical power analysis for the behavioral sciences* (2nd ed.). Hillsdale, NJ: Lawrence Earlbaum Associates.

Corbetta, M. (1998). Frontoparietal cortical networks for directing attention and the eye to visual locations: identical, independent, or overlapping neural systems. *Proceedings of the National Academy of Sciences of the United States of America, 95*, 831–838.

Corbetta, M., Patel, G., and Shulman, G. L. (2008). The reorienting system of the human brain: From environment to theory of mind. *Neuron*, *58*, 306–324.

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

Craighero, L., Nascimben, M., and Fadiga, L. (2004). Eye position affects orienting of visuospatial attention. *Current Biology, 14*, 331–333.

Crowdy, K. A., Hollands, M. A., Ferguson, I. T. and Marple-Horvat, D. E. (2000) Evidence for interactive locomotor and oculomotor deficits in cerebellar patients during visually guided stepping. *Experimental Brain Research, 135*, 437-54.

Crowdy, K. A., Kaur-Mann, D., Cooper, H. L., Mansfield, A. G., Offord, J. L. and Marple-Horvat, D. E. (2002) Rehearsal by eye movement improves visuomotor performance in cerebellar patients. *Experimental Brain Research, 146*, 244-7.

Culham, J. C., Brandt, S., Cavanagh, P., Kanwisher, N. G., Dale, A. M., and Tootell, R. B. H. (1998). Cortical fMRI activation produced by attentive tracking of moving targets. *Journal of Neurophysiology, 80*, 2657-2670.

Derakshan, N., Ansari, T.L., Hansard, M., Shoker, L., and Eysenck, M.W. (2009). Anxiety, inhibition, efficiency and effectiveness: An investigation using the antisaccade task. *Experimental Psychology, 56*, 48–55.

Deubel, H., and Schneider, W.X. (1996). Saccade target selection and object recognition: Evidence for a common attentional mechanism. *Vision Research, 36*, 1827–1837.

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

Dohmen, T.J. (2008). Do professionals choke under pressure? *Journal of Economic Behavior and Organization, 65*, 636-653

Easterbrook, J.A. (1959). The effect of emotion on cue utilization and the organization of behavior. *Psychological Review, 66*, 183–201.

Egloff, B., and Hock, M. (2001). Interactive effects of state anxiety and trait anxiety on emotional Stroop interference. *Personality and Individual Differences, 31,* 875–882.

Ericsson, K.A., and Kintsch, W. (1995). Long-term working memory. *Psychological Review, 102*, 211-245.

Eysenck, M.W. (1982). *Attention and arousal: Cognition and performance*. Berlin: Springer-Verlag.

Eysenck, M. W. (1992). *Anxiety: The cognitive perspective.* Hove, England: Erlbaum.

Eysenck, M. W. (1996) Anxiety, Processing Efficiency Theory and Performance. In Battman, W. and Dutke, S. (Eds.) *Processes of the Molar Regulation of Behaviour.* Lengerich, Pabst Science

Eysenck, M. W., and Byrne, A. (1992). Anxiety and susceptibility to distraction. *Personality and Individual Differences, 13,* 793-798.

Eysenck, M.W., and Calvo, M.G. (1992). Anxiety and performance: The processing effciency theory. *Cognition and Emotion, 6*, 409-434.

Eysenck, M.W., and Derakshan, N. (in press). New perspectives on attentional control theory. *Personality and Individual Differences*.

Eysenck, M.W., Derakshan, N., Santos, R., and Calvo, M.G. (2007). Anxiety and cognitive performance: Attentional control theory. *Emotion*, *7,* 336–353.

Findlay, J. M., and Gilchrist, I. D. (1998). Eye guidance during visual search. In G. Underwood, *Eye guidance in reading and scene perception* (pp. 297–314). Amsterdam: Elsevier.

Fisher, A.C., and Zwart, E.F. (1982). Psychological analysis of athlete's anxiety responses. *Journal of Personality and Social Psychology, 58*, 844–854.

French, K.E., Spurgeon, J. H. and Nevett, M.E. (2005). Expert-novice differences in cognitive and skill execution of youth baseball performance, *Research Quarterly for Exercise and Sport, 66,* 194-201.

Gielen, C. C., van den Heuvel, P. J., and van Gisbergen, J. A. (1984). Coordination of fast eye and arm movements in a tracking task. *Experimental Brain Research, 56*, 154–161.

Gould, D., and Krane, V. (1992). The arousal-performance relationship: Current status and future directions. In T. Horn (Ed.), *Advances in sport psychology*. Champaign, IL: Human Kinetics.

Greenlees, I.A., Leyland, A., Thelwell, R., and Filby, W. (2008). Soccer penalty takers' uniform colour and pre-penalty kick gaze affect the impressions formed of them by opposing goalkeepers. *Journal of Sports Sciences, 26*, 569–576.

Hardy, L., Jones, G.J., and Gould, D. (1996). *Understanding psychological preparation for sport: Theory and practice of elite performers.* Wiley: New York

Harle, S., and Vickers, J. N. (2001). Training quiet eye (QE) improves accuracy in the basketball free throw. *The Sport Psychologist*, *15*, 289-305.

Hayhoe, M.M., Shrivastava, A., Mruczek, R., and Pelz, J.B. (2003). Visual memory and motor planning in a natural task. *Journal of Vision*, *3*, 49–63.

Helsen, W. F. and Starkes, J. L. (1999) A multidimensional approach to skilled
perception and performance in sport. *Applied Cognitive Psychology, 13***,** 1-27.

Henderson, J.M. (2003). Gaze control during real world scene perception. *Trends in
Cognitive Sciences, 7*, 498-504.

Hill, R.A., and Barton, R.A. (2005). Red enhances human performance in contests.
Nature, 435, 293.

Hoffman, J.E., and Subramaniam, B. (1995). The role of visual attention in saccadic eye
movements. *Perception and Psychophysics, 57*, 787-795

Houtman, I.L.D., and Bakker, F.C. (1989). The anxiety thermometer: A validation
study. *Journal of Personality Assessment, 53*, 575–582.

Howell, D.C. (2002). *Statistical methods for psychology* (5th ed.). Boston MA: PWS-
Kent.

Jackson, J. (2005, June5).Triumph and despair: Bruce Grobbelaar. *Observer Sport
Monthly*. Retrieved October 20, 2009, from
http://observer.guardian.co.uk/osm/story/0,,1496 653,00.html

Janelle, C.M. (2002). Anxiety arousal and visual attention: a mechanistic account of
performance variability. *Journal of Sports Sciences, 20*, 237–251.

Janelle, C., and Hatfield, B. (2008). Visual attention and brain processes that underlie
expert performance: Implications for sport and military psychology. *Military
Psychology, 20*, 39-69.

Janelle, C. M., Hillman, C. H., Apparies, R. J., Murray, N. P., Meii, L., Fallon, E. A.
and Hatfield, B. D. (2000). Expertise differences in cortical activation and gaze

behaviour during rifle shooting. *Journal of Sport and Exercise Psychology, 22,* 167-182.

Janelle, C.M., Singer, R.N., and Williams, A.M. (1999). External distraction and attentional narrowing: Visual search evidence. *Journal of Sport and Exercise Psychology, 2*1, 70–91.

Jones, G. (1995). More than just a game: Research developments and issues in competitive anxiety in sport. *British Journal of Psychology, 86,* 449-478.

Jordet, G. (2009a). When superstars flop: Public status and choking under pressure in international soccer penalty shootouts. *Jornal of Applied Sport Psychology, 21*, 125-130.

Jordet, G. (2009b). Why do English players fail in soccer penalty shootouts? A study of team status, self-regulation, and choking under pressure. *Journal of Sports Sciences, 27*, 97–106.

Jordet, Elferink-Gemser, Lemmink, and Visscher, (2006). The "Russian roulette" of soccer?: Perceived control and anxiety in a major tournament penalty shootout. *International Journal of Sport Psychology*, *37*, 281-298

Jordet, G., and Hartman, E. (2008). Avoidance motivation and choking under pressure in soccer penalty shootouts. *Journal of Sport and Exercise Psychology, 30,* 450-457

Jordet, G., Hartman, E., and Sigmundstad, E. (2009). Temporal links to performing under pressure in international soccer penalty shootouts. *Psychology of Sport and Exercise, 10*, 621–627.

Jordet, G., Hartman, E., Visscher, C., and Lemmink, K.A.P.M. (2007). Kicks from the penalty mark in soccer: The roles of stress, skill, and fatigue for kick outcomes. *Journal of Sports Sciences, 25*, 121–129.

Keogh, E., and French, C. C. (2001). Test anxiety, evaluative stress, and susceptibility to distraction from threat. *European Journal of Personality, 15,* 123–141.

Klein, R. (1979). Does oculomotor readiness mediate cognitive control of visual attention? *Attention and Performance VIII*. Hillsdale, N.J: Lawrence Erlbaum and associates.

Kowler, E., Anderson, E., Dosher, B., and Blaser, E. (1995). The role of attention in the programming of saccades. *Vision Research, 35*, 1897–1916

Krane, V. (1994). The mental readiness form as a measure of competitive state anxiety. *The Sport Psychologist, 8*, 189–202.

Kuhn, W. (1988). Penalty-kick strategies for shooters and goalkeepers. In T. Reilly, A. Lees, K. Davids, and W.J.Murphy (Eds.), *Science and football* (pp.489-492). London: E and FN Spon.

Land, M.F. (2009). Vision, eye movements, and natural behavior. *Visual Neuroscience, 26*, 51–62.

Land, M.F., and Furneaux, S. (1997). The knowledge base of the oculomotor system. *Philosophical Transactions*, Royal Society of London, Series B, *352*, 1231–1239.

Land, M.F., Mennie, N. and Rusted, J. (1999). The roles of vision and eye movements in the control of activities of daily living. *Perception 28*, 1311–1328.

Liebert, R. M. and Morris, L. W. (1967) Cognitive and emotional components of test anxiety: a distinction and some initial data. *Psychological Reports, 20*, 975-8.

Lox, C.L. (1992). The role of perceived threat as a cognitive component of state anxiety and confdence. *Perceptual and Motor Skills, 75*, 1092–1094.

Lundqvist, C., and Hassmén, P. (2005). Competitive State Anxiety Inventory-2 (CSAI-2): Evaluating the Swedish version by confirmatory factor analyses. *Journal of Sports Sciences, 23*, 727-736.

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

Marple-Horvat, D.E., Chattington, M., Anglesea, M., Ashford, DG., Wilson, M., Keil, D. (2005). Prevention of coordinated eye movements and steering impairs driving performance. *Experimental Brain Research, 163*, 411-420

Martell, S.G., and Vickers, J.N. (2004). Gaze characteristics of elite and near-elite ice hockey players. *Human Movement Science, 22*, 689–712.

Martens, R., Burton, D., Vealey, R.S., Bump, L., and Smith, D.E. (1990). Development and validation of the Competitive State Anxiety Inventory-2. In R. Martens, R.S. Vealey, and D. Burton (Eds.), *Competitive anxiety in sport* (pp. 117–178). Champaign, IL: Human Kinetics.

Masters, R.S.W., van der Kamp, J., and Jackson, R.C. (2007). Imperceptibly off-center goalkeepers influence penalty-kick direction in soccer. *Psychological Science, 18*, 222–223.

McGarry, T., and Franks, I.M. (2000). On winning a penalty shootout in soccer. *Journal of Sport Sciences, 18*, 401-409.

McPherson, S.L. (1999). Tactical differences in problem representations and solutions in collegiate varsity and beginner women tennis players. *Research Quarterly for Exercise and Sport, 70,* 369-284.

McPherson, S.L. (2000). Expert-novice differences in planning strategies during collegiate singles tennis competition. *Journal of Sport and Exercise Psychology, 22,* 39-62.

McPherson, S.L., and Vickers, J.N. (2004) .Cognitive control in motor expertise. *International Journal of Sport and Exercise Psychology, 2*, 274–300.

Miller, R. (1996). Shooter vs. keeper: A tense battle. Games are won and lost by penalty kicks and PK tiebreakers. *Soccer Journal*, 41, 59–62.

Miyake, A., Friedman, N. P., Emerson, M. J., Witzki, A. H., Howerter, A., and Wager, T. D. (2000). The unity and diversity of executive functions and their contributions to complex "frontal lobe" tasks: A latent variable analysis. *Cognitive Psychology, 41,* 49-100.

Mogg, K., Bradley, B. P., Dixon, C., Fisher, S., Twelftree, H., and McWilliams, A. (2000). Trait anxiety, defensiveness and selective processing of threat: An investigation using two measures of attentional bias. *Personality and Individual Differences, 28,* 1063-1077.

Motter, B. C., and Belky, E. J. (1997). The guidance of eye movements during active visual search. *Vision Research*, *38*, 1805-1818.

Morya. E., Ranvaud, R., and Pinheiro, W.M, (2003). Dynamics of visual feedback in a laboratory simulation of a penalty kick. *Journal of Sport Sciences, 21*, 87-95.

Murray, N.P., and Janelle, C.M. (2003). Anxiety and performance: A visual search examination of the processing effciency theory. *Journal of Sport and Exercise Psychology, 25,* 171–187.

Murray, N.P., and Janelle, C.M. (2007). Event-related potential evidence for the processing effciency theory. *Journal of Sports Sciences, 25*, 161–171.

Nagano, T., Kato, T., and Fukuda, T. (2006). Visual behaviors of soccer players while kicking with the inside of the foot. *Perceptual and Motor Skills, 102*, 147–156.

Neggers, S.F., and Bekkering, H. (2000). Coordinated control of eye and hand movements in dynamic reaching. *Human Movement Science, 21*, 349–376.

Neggers, S.F.W., and Bekkering, H. (1999). Integration of visual and somatosensory target information in goal-directed eye and arm movements. *Experimental Brain Research*, *125*, 97–107.

Neggers, S. F., and Bekkering, H. (2001). Gaze anchoring to a pointing target is present during the entire pointing movement and is driven by a non-visual signal. *Journal of Neurophysiology, 86*, 961–970.

Neiss, R. (1988) Reconceptualizing arousal: psychobiological states in motor performance. *Psychological Bulletin, 103*, 345-66.

Nieuwenhuys, A., and Oudejans, R.R.D. (2009). Effects of anxiety on handgun shooting behavior of police officers: A pilot study. *Anxiety, Stress and Coping, 22*, 1–9.

Nieuwenhuys, A., Pijpers, J.R., Oudejans, R.R.D., and Bakker, F.C. (2008). The influence of anxiety on visual attention in climbing. *Journal of Sport and Exercise Psychology, 30*, 171–185.

Oudejans, R. R. D., Koedijker, J., Bleijendaal, I., and Bakker, F. C. (2005). The education of attention in aiming at a far target: Training visual control in basketball jump shooting. *International Journal of Sport and Exercise Psychology, 3*, 197-221.

Oudejans, R. R. D., Kuijpers, W., Kooijman, C. C, and Bakker, F. C. (2010). Thoughts and attention of athletes under pressure: skill-focus or performance worries? *Anxiety, Stress and Coping,*

Panchuk, D., and Vickers, J.N. (2006). Gaze behaviours of goaltenders under spatial temporal constraints. *Human Movement Science, 25*, 733-752.

Pelz, J.B., and Canosa, R. (2001). Oculomotor behavior and perceptual strategies in complex tasks. *Vision Research, 41*, 3587–3596.

Pijpers, J.R., Oudejans, R.R.D., Holsheimer, F., and Bakker, F.C. (2003). Anxiety-performance relationships in climbing: A process-oriented approach. *Psychology of Sport and Exercise, 4*, 283–304.

Posner, M.I. (1980). Orientating of attention. *Quarterly Journal of Experimental Psychology, 32*, 3-25

Posner, M. and M. Raichle (1994). *Images of Mind*. New York, W. H. Freeman and Company.

Raab, M., and Johnson, J. G. (2007). Expertise-based differences in search and option generation strategies. *Journal of Experimental Psychology: Applied, 13,* 158-170.

Ripoll, H., Kerlirzin, Y., Stein, J.F., and Reine, B. (1995). Analysis of information processing, decision-making, and visual search strategies in complex problem solving sport situations. *Human Movement Science, 14,* 325-349.

Rodrigues, S.T., Vickers, J.N., and Williams, A.M. (2002). Head, eye and arm coordination in table tennis: an exploratory study. *Journal of Sport Sciences, 20,* 171-186.

Sailer, U., Flanagan, J.R., and Johansson, R.S. (2005). Eye-hand coordination during learning of a novel visuomotor task. *Journal of Neuroscience, 25,* 8833–8842.

Sarason, I. G. (1988). Anxiety, self-preoccupation and attention. *Anxiety Research, 1,* 3-7.

Savelsbergh. G.J.P. and van der Kamp, J. (2000). Information in learning to co-ordinate and control movements: Is there a need for specificity of practice? *International Journal of Sport Psychology, 31,* 467-484.

Savelsbergh, G. J. P., van der Kamp, J., Williams, A. M., and Ward, P. (2005). Anticipation and visual search behaviour in expert soccer goalkeepers. *Ergonomics, 48,* 1686-1697.

Savelsbergh, G. J. P., Williams, A. M., van der Kamp, J., and Ward, P. (2002). Visual search, anticipation and expertise in soccer goalkeepers. *Journal of Sports Sciences, 20,* 279-287.

Sheliga, B.M., Riggio, L., and Rizzolatti, G. (1995). Spatial attention and eye movements. *Experimental Brain Research, 105*, 261-275.

Shepherd, M., Findlay, J. M., and Hockey, R. J. (1986). The relationship between eye movements and spatial attention. *Quarterly Journal of Experimental Psychology*, *38,* 475-491.

Shinoda, H., Hayhoe, M. M., and Shrivastava, A. (2001). What controls attention in natural environments. *Vision Research, 41,* 3535-3545.

Singer, R., Cauraugh, J., Chen, D., Steinberg, G.M., and Frehlich, S. G. (1996). Visual search, anticipation, and reactive comparisons between highly-skilled and beginning tennis players. *Journal of Applied Sport Psychology, 8*, 9-26.

Smith, D.T., Rorden, C., and Jackson, S.R. (2004). Exogenous orienting of attention depends upon the ability to execute eye movements. *Current Biology, 14*, 792–795.

Smith, N. C., Bellamy, M., Collins, D. J. and Newell, D. (2001). A test of processing efficiency theory in a team sport context. *Journal of Sports Sciences*, *19***,** 321-332.

Treisman, A., and Gormican, S. (1988). Feature analysis in early vision. *Psychological Review, 95*, 15-30.

Van der Kamp, J. (2006). A field simulation study of the effectiveness of penalty kick strategies in soccer: Late alteration of kick direction increase errors and reduce accuracy. *Journal of Sports Sciences, 24*, 467–477.

Van der Kamp, J. and Masters, R.S.W. (2008). The human Muller-Lyer illusion in goalkeeping. *Perception, 37*, 951–954.

Van der Stigchel, S., and Theeuwes, J. (2007). The relationship between covert and overt attention in endogenous cuing. *Perception and Psychophysics, 69*, 719–731.

Vercher, J-L., Magenes, G., Prablanc, C., and Gauthier, G.M. (1994). Eye-head-hand coordination in pointing at visual targets: spatial and temporal analysis. *Experimental Brain Research, 99*, 507-523.

Vickers, J.N. (1992). Gaze control in putting. *Perception, 21*, 117– 132.

Vickers, J.N. (1996). Visual control when aiming at a far target. *Journal of Experimental Psychology: Human Perception and Performance, 2*, 324–354.

Vickers, J.N. (2004). The Quiet Eye: It's the difference between a good putter and a poor one. *Golf Digest*, January, 96-101.

Vickers, J.N. (2007). *Perception, cognition and decision training: The quiet eye in action.* Champaign IL: Human Kinetics.

Vickers, J.N., and Adolphe, R.M. (1997). Gaze behaviour during a ball tracking and aiming skill. *International Journal of Sports Vision, 4*, 18-27.

Vickers, J.N., and Williams, A.M. (2007). Performing under pressure: The effects of physiological arousal, cognitive anxiety, and gaze control in biathlon. *Journal of Motor Behavior, 39*, 381–394.

Vine, S.J., Wilson, M. R. (2010) Quiet eye training: Effects on learning and performance under pressure. *Journal of Applied Sport Psychology, 22*, 361-376

Vine, S.J, and Wilson, M. R. (in press) The influence of quiet eye training and pressure on attentional control in a visuo-motor task. *Acta Psychologica*

Vine, S. J, Moore, L.J, and Wilson, M. R (2011) Quiet Eye training facilitates competitive putting performance in elite golfers. *Frontiers in Psychology* doi: 10.3389/fpsyg.2011.00008

Wegner, D.M. (1994). Ironic processes of mental control. *Psychological Review, 101*, 34–52.

Wegner, D. M., Ansfield, M., and Pilloff, D. (1998). The putt and the pendulum: Ironic effects of the mental control of action. *Psychological Science, 9*, 196-199.

Weierich, M.R., Treat, T.A., and Hollingworth, A. (2008). Theories and measurement of visual attentional processing in anxiety. *Cognition and Emotion, 22*, 985–1018.

Williams, A.M., Davids, K., Burwitz, L., and Williams, J.G. (1993). Visual search and sports performance. *The Australian Journal of Science and Medicine in Sport, 25*, 147-204.

Williams, A.M., Davids, K., Burwitz, L., and Williams, J.G. (1994). Visual search strategies in experienced and inexperienced soccer players. *Research Quarterly for Exercise and Sport, 6*, 127-135.

Williams, A.M., and Elliott, D. (1999). Anxiety, expertise, and visual search strategy in karate, *Journal of Sport and Exercise Psychology, 21*, 326-375.

Williams, M.A., Singer, R.N., and Frehlich, S.G. (2002). Quiet eye duration, expertise and task complexity in near and far aiming tasks. *Journal of Motor Behaviour, 34,* 197-207.

Williams, A.M., Vickers, J.N., and Rodrigues, S. (2002). The Effects of Anxiety on Visual Search, Movement Kinematics, and Performance in Table Tennis: A Test

of Eysenck and Calvo's Processing Effciency Theory. *Journal of Sport and Exercise Psychology, 24*, 438–455.

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

Wilson, M., Chattington, M. and Marple-Horvat, D.E. (2008). Eye movements drive steering: The effect of reduced eye movement distribution on steering and driving performance. *Journal of Motor Behaviour, 40*, 190-202.

Wilson, M., Chattington, M., Marple-Horvat, D.E., and Smith, N.C. (2007). A comparison of self-focus versus attentional explanations of choking. *Journal of Sport and Exercise Psychology, 29*, 439–456.

Wilson, M., Coleman, M., McGrath, J. (2010). Developing basic hand-eye coordination skills for laparoscopic surgery using gaze training. *British Journal of Urology International*, *105*, 1356-1358.

Wilson, M.R., and Pearcey, R. (2009). The visuomotor control of straight and breaking golf putts. *Perceptual and Motor Skills, 109*, 555–562.

Wilson, M., Smith, N.C., Chattington, M., Ford, M., and Marple-Horvat, D.E. (2006). The role of effort in moderating the anxiety-performance relationship: Testing the predictions of processing effciency theory in simulated rally driving. *Journal of Sports Sciences, 24*, 1223–1233.

Wilson, M., Smith, N.C., and Holmes, P.S. (2007T). The role of effort in moderating the anxiety-performance relationship: Testing the conficting predictions of processing effciency theory and the conscious processing hypothesis. *The British Journal of Psychology, 98*, 411–428.

Wilson, M.R., Vine, S.J., and Wood, G. (2009). The influence of anxiety on visual

    attentional control in basketball free throw shooting. *Journal of Sport and*

    Exercise Psychology, 31, 1–19.

Wood, G., and Wilson, M. (2008). Anxiety, attention and penalty kicking performance:

    An external focus of attention may provide protection against the negative

    effects of anxiety. Paper presented at *The British Psychological Society Annual*

    Conference, Dublin, Ireland. (Book of Abstracts, 74).

Wood, G., and Wilson, M. R. (2010). The eyes have it! The psychology of success and

    failure for penalty takers. *Soccer Journal, Nov/Dec*, 14-15.

Woodman T, and Davis, P. A. (2008) The role of repression in the incidence of ironic

    errors. The *Sport Psychologist, 22*, 183-198

Yiannakos, A., and Armatas, V. (2006). Evaluation of the goal scoring patterns in

    European Championship in Portugal 2004. *International Journal of Performance*

    Analysis is Sport, 6, 178-188.