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The Influence of Anxiety on Visual Attentional Control in Basketball Free Throw Shooting

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The aim of this study was to test the predictions of attentional control theory using the quiet eye period as an objective measure of attentional control. Ten basketball players took free throws in two counterbalanced experimental conditions designed to manipulate the anxiety they experienced. Point of gaze was measured using an ASL Mobile Eye tracker and fixations including the quiet eye were determined using frame-by-frame analysis. The manipulation of anxiety resulted in significant reductions in the duration of the quiet eye period and free throw success rate, thus supporting the predictions of attentional control theory. Anxiety impaired goal-directed attentional control (quiet eye period) at the expense of stimulus-driven control (more fixations of shorter duration to various targets). The findings suggest that attentional control theory may be a useful theoretical framework for examining the relationship between anxiety and performance in visuomotor sport skills.

Keywords: quiet eye, gaze behavior, processing efficiency, visuomotor skills, pressure

Anxiety's influence on performance continues to be one of the main research interests for sport psychologists (Woodman & Hardy, 2001). Anxiety is postulated to occur as a result of threat and is related to the subjective evaluation of a situation with regard to one's self-esteem (Eysenck, 1992). Several theorists have suggested that the negative performance effects of anxiety are due to the manner in which worry and other forms of cognitive interference occupy attention (e.g., Kahneman, 1973; Sarason, 1988). One theory that provides an explanatory account of the mechanisms involved in the anxiety–performance relationship, and that has been the focus of recent research in sport settings, is processing efficiency theory (PET; Eysenck & Calvo, 1992).

Processing efficiency theory predicts that cognitive anxiety in the form of worry has two main effects. First, it reduces the processing and storage capacity of the central executive of working memory (Baddeley, 1986), thereby reducing the attentional resources available for the task at hand. Second, worry can have a

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motivational role, stimulating increases in on-task effort and auxiliary processing resources and strategies. This compensatory effort is aimed at maintaining performance at a desired level and serves to reduce, or eliminate, apprehension associated with worrisome thoughts related to the aversive consequences of poor performance (Eysenck & Calvo, 1992). The efficiency by which performers process information when anxious is therefore decreased, potentially resulting in poorer performance (Janelle, 2002).

The predictions of PET have recently been tested using a variety of measures of processing efficiency in a number of sport settings, including golf putting (Wilson, Smith, & Holmes, 2007), table tennis (Williams, Vickers, & Rodrigues, 2002), simulated archery (Behan & Wilson, 2008), karate defense techniques (Williams & Elliott, 1999), field hockey (Wilson & Smith, 2007), volleyball (Smith, Bellamy, Collins & Newell, 2001), climbing (Nieuwenhuys, Pijpers, Oudejans & Bakker, 2008), and simulated driving (Murray & Janelle, 2003, 2007; Wilson, Smith, Chattington, Ford, & Marple-Horvat, 2006; Wilson, Chattington, Marple-Horvat, & Smith, 2007). Of particular interest to the current investigation are the findings from studies that have used indices of gaze behavior to test the predictions of PET. Such findings provide more specific insight into how visual attentional control is affected in threatening settings rather than changes in the more generic concept of processing efficiency (Wilson, 2008).

In line with the predictions of PET, anxiety has been shown to reduce the efficiency of gaze behavior, both in motor tasks requiring visual search and detection, and tasks requiring aiming. While limited in number, the findings from such studies have been relatively consistent, with increased anxiety being reflected in less efficient visual search strategies and gaze orientation behavior (see Janelle, 2002, and Wilson, 2008, for reviews). First, in tasks requiring the detection of peripherally presented targets, performers show higher search rates, characterized by more foveal fixations of shorter duration to the target areas when anxious as opposed to control conditions (e.g., Murray & Janelle, 2003; Williams, Vickers, et al., 2002). This finding has been taken to reflect a decrease in efficiency, as a greater number of fixations appear needed to gather the same information acquired by fewer fixations in the low anxiety condition. In addition, as eye movements between successive fixations, known as *saccades*, are believed to suppress information processing (Bridgeman, Hendry, & Start, 1975), a visual search strategy involving fewer fixations of longer duration allows more time for information extraction and can be thought of as more efficient (Mann, Williams, Ward, & Janelle, 2007).

In aiming tasks, a particular fixation termed the *quiet eye* (Vickers, 1996), defined as the final fixation to a target before the initiation of the motor response, has also been shown to become less efficient under pressure. Vickers proposed that the quiet eye is a period of time when task-relevant environmental cues are processed and motor plans are coordinated for the successful completion of the upcoming task. Theoretically, longer quiet eye periods therefore allow performers an extended duration of programming, while minimizing distraction from other environmental cues (Vickers, 1996).

A number of studies have demonstrated that longer quiet eye periods are indicative of superior performance in aiming tasks (see Vickers, 2007, for a review); however, to date, only two studies have examined the influence of anxiety on the quiet eye period (Behan & Wilson, 2008; Vickers & Williams, 2007). Vickers and

Williams (2007) found that elite biathletes who increased their quiet eye duration during high-pressure competition, compared with low-pressure practice, were less susceptible to sudden performance disruption, or choking, as physiological arousal increased to maximum. Behan and Wilson (2008), in a simulated archery task found that under conditions of elevated cognitive anxiety, quiet eye durations were reduced, as participants took more fixations around the vicinity of the target than they did in the low-pressure condition. These results show that the quiet eye period is sensitive to increases in anxiety and may be a useful index of the efficiency of visual attentional control in aiming tasks.

The preceding discussion reflects the utility of adopting gaze behavior measures to assess the efficiency of visual attention in anxiety-inducing situations. However, while the specific forms of inefficiency (e.g., increased search rate to peripheral targets and reduced quiet eye period) can be explained by current cognitive approaches, such as hypervigilance (Eysenck, 1992) and attentional narrowing (Easterbrook, 1959), there is no overriding theoretical framework to explain the effect of anxiety on the efficiency of attentional control in aiming and visual search tasks. However, a recent theoretical development and extension of PET by Eysenck and colleagues—attentional control theory (ACT; Eysenck, Derakshan, Santos, & Calvo, 2007)—may provide a framework by which the preceding gaze behavior results can be interpreted, and the development of future gaze control research structured.

Attentional control theory (Eysenck et al., 2007) assumes that the effects of anxiety on attentional processes are of fundamental importance in understanding how anxiety influences performance. As anxiety is experienced when a current, valued goal is threatened, this causes attention to be allocated to detecting the source of the threat and deciding how to respond (e.g., Power & Dalgleish, 1997). As a result, processing resources are more likely to be diverted away from task-relevant stimuli and toward task-irrelevant stimuli. This is assumed to be the case irrespective of whether these stimuli are external (e.g., environmental distractors) or internal (e.g., worrying thoughts) (Eysenck et al., 2007). The authors relate this impairment of attentional control to a disruption in the balance of two attentional systems first outlined by Corbetta and Shulman (2002): a goal-directed (top-down) attentional system and a stimulus-driven (bottom-up) 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).

Attentional control theory makes more specific predictions regarding lower level functions of the central executive of working memory that are related to the goal-directed attentional system (Baddeley, 1986). In this way, ACT overcomes some of the limitations of PET (Eysenck & Calvo, 1992) in terms of its lack of precision or explanatory power. While PET suggested that anxiety impairs the processing efficiency of the central executive of working memory, ACT is more precise about the *specific* functions of the central executive that are most adversely affected by anxiety, namely, the inhibition and shifting functions (based on Miyake et al., 2000). It is the impaired functioning of these elements of attentional control (i.e., inhibition and shifting) that is proposed to disrupt the balance between the goal-directed and stimulus-driven attentional systems.

The central prediction of PET, that anxiety impairs processing efficiency more than performance effectiveness, is still retained within ACT. The processing inefficiency caused by the disruption of the inhibition and shifting functions of the central executive does not necessarily lead to decrements in performance effectiveness provided that anxious individuals respond by using compensatory or alternative processing strategies (Eysenck et al., 2007). In outlining future directions for research into ACT, Eysenck et al. discussed the need for investigation into the strategies used by anxious individuals when their processing becomes inefficient. Potential alterations in gaze control strategies, particularly quiet eye, during visuomotor task performance provide an ideal opportunity to accomplish this (see also Nieuwenhuys et al., 2008).

An important consideration when examining gaze behavior indices is the degree to which the location of overt gaze is reflective of the target of covert attention. Although the extent to which gaze behavior accurately represents attention has been questioned (e.g., Kuhn, Tatler, Findlay, & Cole, 2008; Posner & Raichle, 1991; Viviani, 1990), recent research suggests that it is difficult to shift the point of gaze without shifting attention (Henderson, 2003; Shinoda, Hayhoe, & Shrivastava, 2001). Furthermore, the attention shifts that precede goal-directed, saccadic eye movements are directly associated with their preparation and involve some of the same neuronal "machinery" (e.g., Corbetta, 1998). Finally, Eysenck et al. (2007) suggest that direct measures of attentional control, such as gaze indices, should be adopted in order that the influence of anxiety on attention be better understood.

The current study therefore aims to examine the influence of anxiety on the quiet eye period and accuracy of basketball players performing free throws. The basketball free throw was felt to be an appropriate task, as it has been adopted in previous research examining the quiet eye period (e.g., Harle & Vickers, 2001; Vickers, 1996), and a number of standardized definitions and analysis procedures have already been clarified (see Vickers, 2007). In terms of the predictions of ACT, it is evident that the free throw relies heavily on the goal-directed attentional system; therefore, impairment of inhibitory control will likely result in reductions in the quiet eye periods of anxious basketball players. The impairment of inhibitory control should also be reflected in more gazes of shorter duration around the target area (i.e., the basketball hoop) when anxious, owing to increased influence of the stimulus-driven attentional system.

While ACT predicts that performance effectiveness may not necessarily be negatively affected by such reduced efficiency of attentional control, both Vickers and Williams (2007) and Behan and Wilson (2008) found that increased anxiety caused reductions in quiet eye periods and subsequent performance. It is therefore predicted that performance, as measured by free throw percentage accuracy will be worse when participants are anxious if the quiet eye period is significantly reduced.

Method

Participants

Ten male basketball players from university teams (mean age, 20.3 years, *SD* = 0.9) with 7.1 years of experience (*SD* = 1.9) volunteered to take part in the study. All players took free throws for their teams during the current season (mean percentage accuracy, 64.6%, *SD* = 9.91). Participants attended individually and had the general nature of the study explained to them. Written information was provided and written consent was gained from all participants. Local ethics committee approval was obtained before the start of testing.

Apparatus

The free throws were taken from standard distance (i.e., 4.60 m) and to a hoop set at standard height (3.04 m) from the ground. Gaze was measured using an Applied Science Laboratories (ASL; Bedford, MA) Mobile Eye tracker. This lightweight system measures eye line of gaze at 25 Hz, with respect to eye and scene cameras, mounted on a pair of glasses. The system works by detecting two features, 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 Inspiron 6400) installed with Eyevision (ASL) recording software. A circular cursor, representing 1° of visual angle with a 4.5-mm lens, indicating the location of gaze in a video image of the scene (spatial accuracy of ±0.5° visual angle; 0.1° precision) is viewed in real time on the laptop and recorded for offline analysis. The DVCR was linked to the laptop via a 10-m FireWire cable, permitting nearly normal mobility for the participant. The experimenter and the laptop were located behind and to the right of the participant, to minimize distraction.

An externally positioned digital video camera (Canon, MDl01) was located 3 m to the right of the participants, perpendicular to the direction in which they were shooting (i.e., sagittal plane). The view allowed the entire free throw action of each participant to be captured for subsequent offline analyses.

Measures

State Anxiety. State anxiety levels were measured before each block of 10 free throws using the Mental Readiness Form–Likert (MRF-L; Krane, 1994). The MRF-L was developed to be a shorter and more expedient alternative to the CSAI-2 (Martens, Burton, Vealey, Bump, & Smith, 1990), allowing anxiety to be reported during, as well as before, performance. The MRF-L has three bipolar 11-point Likert scales that are anchored between *worried / not worried* for the cognitive anxiety scale, *tense / not tense* for the somatic anxiety scale, and *confident / not confident* for the self-confidence scale. Participants are asked to record how they feel “right now” when completing the scales. Krane’s validation work on the MRF-L revealed correlations between the MRF-L and the CSAI-2 subscales of .76 for cognitive anxiety, .69 for somatic anxiety, and .68 for self-confidence. Mean values were computed for each scale from the participants’ self-reports made beforehand and at set times during each testing condition (see Procedure). As with previous research investigating the effect of worry on sporting performance (e.g., Wilson, Smith, et al., 2007; Wilson, Chattington, et al., 2007), the cognitive anxiety scale provided the main focus for the research.

Fixations. Six key gaze locations were defined: the left rim, right rim, front rim, back rim, backboard, and other, based on previous literature (Harle & Vickers, 2001; Vickers, 1996). Fixations were defined as a gaze that remained on a location (within 1° visual angle), for a minimum of 120 ms, or 3 frames. The number and mean duration of all fixations made during the free throw preparation and execution period were analyzed for a subset of shots (see Procedure).

Quiet Eye Period. The quiet eye period is generally defined as the final fixation directed to a single location or object in the visuomotor workspace within 3° of visual angle (or less) for a minimum of 100 ms. The quiet eye has an onset that occurs before the final movement in the motor task and an offset that occurs when the fixation or tracking deviates off the target by more than 3° of visual angle for more than 100 ms (see Vickers, 2007). For the basketball free throw, the consensus is that the final movement can be categorized as the final extension of the arms, the first video frame in which the angle between upper and lower arm starts to increase (Vickers, 2007). For the current study, the quiet eye was therefore operationally defined as the final fixation to a single location or object in the visuomotor workspace within 1° of visual angle for a minimum of 120 ms (three frames). Quiet eye onset occurred before the initiation of the extension phase of the free throw, and is reported relative to how long it occurred after the initiation of the preparation phase (in milliseconds). Quiet eye offset occurred when the gaze deviated off the fixated location (by 1° or more) for more than three frames. If the cursor disappeared for 1 or 2 frames (e.g., a blink) and then returned to the same location, the quiet eye duration resumed (www.quieteyesolutions.com).

Movement Phases. Three movement phases were highlighted based on a set of strict rules derived from existing research (Vickers, 2007). The preparation phase was coded as a consistent 1000 ms before the first upward movement of the ball for all participants. The lift phase was coded from the first upward movement of the ball until extension of the elbow occurred. The extension phase was coded from the first extension at the elbow until the ball left the fingertips. Although ACT makes no predictions about how anxiety may influence the timing of participants' movement phases, these results are reported for completeness.

Performance. The performance measure consisted of the number of shots required to achieve the criterion level of 10 successful and 10 unsuccessful free throws. Specifically, free throw percentage success in each condition was adopted as the measure of performance effectiveness in the current study (number of successful throws × 100 / total number of throws).

Procedure

After reading the written information introducing the study and providing informed consent, participants were allowed to take 20 practice free throws at will to become familiar with the testing surroundings. After a 1-min break they were asked to take 10 free throws without the eye tracker being fitted and to score as many baskets as possible. Participants were then fitted with the eye-tracking device, and calibration took place using a grid presented at the same distance as the hoop, displaying nine individually numbered crosses arranged in a 3 × 3 format. Participants were then asked to take 10 more free throws and score as many shots as possible. Performance was recorded in both conditions to ensure that there were no changes in performance due to the wearing of the eye tracker.

Participants were then provided with instructions related to the condition in which they were going to perform under and were asked to give a reading from the three scales on the MRF-L. Before every block of 10 shots, participants were asked to face the external camera and clap their hands in front of their face, in order that a clear event could be used to time-lock the footage from the external camera and the eye-tracker scene camera for subsequent offline analyses. Each block of 10 free throws was split into five sets of two consecutive throws, with an experimenter returning the ball to the participant after each throw. This was to ostensibly follow the typical game situation whereby free throws occur in pairs. After every pair of free throws, a quick calibration check was performed using the calibration grid and several distinguished points on the backboard. If necessary, the line of gaze was recalibrated quickly before proceeding with the testing protocol.

After every 10 free throws, the video data were saved and the participants were then asked to report their current anxiety levels using the MRF-L. This procedure was repeated until the participants had performed 10 successful free throws and 10 unsuccessful free throws (as Vickers, 1996), although they were unaware of this requirement. The participants were then allowed a 5-min rest before the second condition was explained and the same testing procedure followed. At the end of the testing period, participants were debriefed about the true purpose of the study.

Experimental Conditions

Participants were asked to take free throws in two counterbalanced conditions, designed to manipulate the level of anxiety experienced. In the control condition, nonevaluative instructions were provided to participants, asking them to do their best but stressing that their success rate would not to be used for comparison with other participants. In the high-threat condition, several manipulations were used to attempt to ensure that high levels of pressure were created (see Behan & Wilson, 2008; Murray & Janelle, 2003). Participants were informed that their success rate and performance levels were to be compared among their teammates and that their team's average success rate was going to be compared with other teams within the same competitive league.

Financial rewards were offered to the three participants with the best free throw accuracy (£30 for first place, £20 for second, and £10 for third). Noncontingent feedback was also used (see Williams & Elliott, 1999), whereby participants were informed that their previous 20 free throws put them in the bottom 30% when compared with other participants who had already taken part. The previous 20 free throws were either from their warm-up or the control condition depending upon whether they were completing the high-threat condition first or second. The participants were informed that being in the bottom 30% meant that the data were of no use for the study and that they should try and be more accurate.

Data Analysis

Fixation and movement phase data were calculated via frame-by-frame analysis of the eye tracker and external video camera files, using Quiet Eye Solutions software (Quiet Eye Solutions Inc.). Figure 1 shows the split screen view of the Vision-in-Action (Vickers, 1996) video data, with the left side showing the external video of the participant performing the free throw. The right side shows the view from the scene camera of the eye tracker, with the point of gaze indicated by a circular cursor, representing a 1° visual angle (located just under the front of the hoop). The software time-locks the two video files and allows coding of the movement phases from the external video, in relation to the coding of the gaze behavior (gaze location and duration) from the eye tracker.

As with previous studies examining the quiet eye period (e.g., Behan & Wilson, 2008; Harle & Vickers, 2001; Vickers, 1996; Williams, Singer, et al., 2002), a subset of shots were selected for frame-by-frame analyses. If 10 successful shots were made before 10 misses, then all misses were included and a randomly selected group of 10 successful shots. This procedure was reversed if 10 misses occurred first. A random number generator (www.random.org) was used to select the 10 random shots to be analyzed by inputting the total number of successful shots or misses into the generator and selecting the first 10 numbers generated. Values for gaze behavior and movement phase–dependent variables were calculated for the10 successful shots and 10 misses for each condition and used in subsequent statistical analyses.

MOTOR: 121jh(21-30)cond1(motor).avi 36secs. Fr 605

GAZE: 121jh(21-30)cond1_00000.avi 41secs. Fr 683

0:00:27.32 [00018476]

Media Filename: 121jh(21-30)cond1_00

Trial #: 2

1) 0 0 0 ms
2) 0 0 0 ms
3) 0 0 0 ms
Trial Duration: 0 ms

Figure 1 — A screen grab of the Quiet Eye Solutions software analysis environment; showing the external video of the participant (left), the view from the scene camera of the eye-tracker (right) and the coding entry fields (center)

Results

Performance accuracy percentages in the familiarization condition (with and without the eye tracker) were subjected to paired samples *t* test analysis. Anxiety and performance accuracy data were also subjected to paired samples *t* test analyses (control vs. high-threat conditions). Quiet eye, fixation, and movement phase data were all subjected to a fully repeated measures 2 × 2 × 10 ANOVA: threat (control, high) × accuracy (hit, miss) × trial (1–10). Where the sphericity assumption was violated, Greenhouse–Geisser corrections were applied. Effect sizes (ω^2) were calculated as outlined in Howell (2002).

Familiarization Performance

Percentage accuracy was 56.0% (*SD* = 20.11) while wearing the eye tracker and 51.0% (*SD* = 11.97) while not wearing the eye tracker. This difference was not significant, $t(9) = .86$, $p = .41$, $\omega^2 = .38$, suggesting that wearing the eye tracker had no effect on shooting performance.

State Anxiety: MRF-L

Participants reported significantly higher cognitive anxiety scores in the high-threat (mean rating of 5.05, *SD* = .90) than in the control (mean rating of 3.29, *SD* = 1.24) condition, $t(9) = 5.17$, $p < .005$, $\omega^2 = 1.30$. Somatic anxiety scores were also significantly higher in the high-threat (mean rating of 5.63, *SD* = 1.01) than the control (mean rating of 3.60, *SD* = .84) condition, $t(9) = 5.97$, $p < .001$, $\omega^2 = 2.10$. Self-confidence scores were significantly lower in the high-threat (mean rating of 6.54, *SD* = 1.66) than the control (mean rating of 7.73, *SD* = 1.26) condition, $t(9) = 2.57$, $p < .05$, $\omega^2 = .86$.

Performance

Performance, as measured by free throw percentage accuracy, was lower in the high-threat (50.50%, *SD* = 5.07) than in the control (68.60%, *SD* = 11.02) condition, $t(9) = 5.52$, $p < .001$, $\omega^2 = 1.50$.

Quiet Eye Period Duration

Significant main effects were found for threat, $F(1, 9) = 12.11$, $p < .01$, $\omega^2 = .55$, and accuracy, $F(1, 9) = 30.13$, $p < .001$, $\omega^2 = .80$. There was no main effect for trial, $F(4.4, 39.8) = .83$, $p = .52$, and no significant interaction effects. Participants had longer quiet eye periods in the control condition compared with the high-threat condition, and for successful shots (hits) compared with misses. The quiet eye duration data are presented in Figure 2 (top).

Quiet Eye Onset

A significant main effect was found for accuracy, $F(1, 9) = 9.98$, $p < .05$, $\omega^2 = .30$, with earlier quiet eye onsets occurring for successful shots (hits) as opposed to misses. There were no significant main effects for threat, $F(1, 9) = 2.43$, $p = .15$,

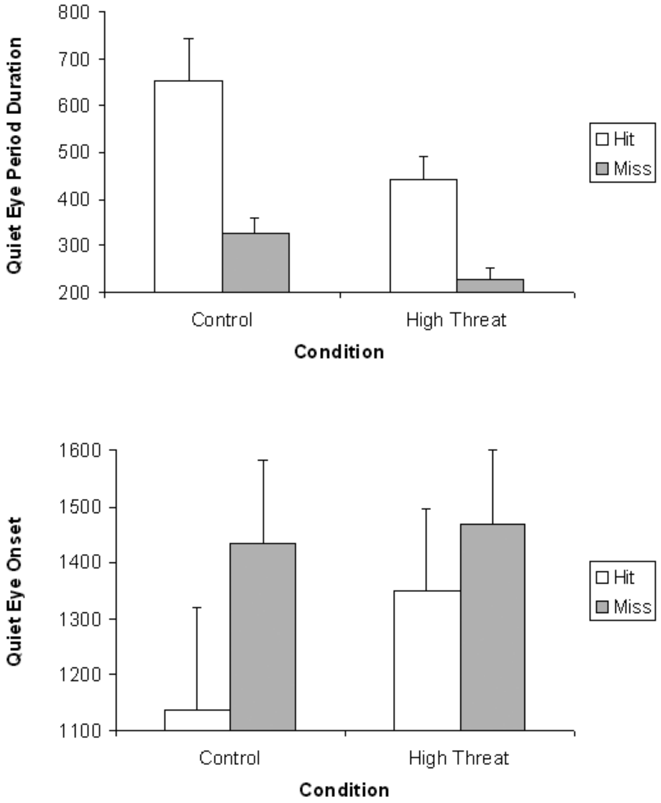

Figure 2 — Quiet eye period data: Mean quiet eye duration (ms; top) and onset (ms after initiation of preparation phase; bottom) for successful (hits) and unsuccessful (misses) shots, during control and high threat conditions (with standard error bars).

$\omega^2 = .18$, or trial, $F(9, 81) = 1.18$, $p = .12$, and no significant interaction effects. The quiet eye onset data are presented in Figure 2 (bottom).

Number of Fixations

Significant main effects were found for threat, $F(1, 9) = 32.44$, $p < .001$, $\omega^2 = .82$, and accuracy, $F(1, 9) = 6.10$, $p < .05$, $\omega^2 = .25$. There was no significant main effect for trial, $F(9, 81) = .87$, $p = .56$, and no significant interaction effects. Participants used more fixations in the high threat as opposed to control condition and for misses as opposed to successful shots (hits). The fixation count data are presented in Figure 3 (top).

Mean Fixation Duration

Significant main effects were found for threat, $F(1, 9) = 63.98$, $p < .001$, $\omega^2 = 2.18$, and accuracy, $F(1, 9) = 7.40$, $p < .05$, $\omega^2 = .40$. There was no significant main effect for trial, $F(9, 81) = .57$, $p = .66$, and no significant interaction effects. Participants used shorter duration fixations in the high-hreat as opposed to control condition and for misses as opposed to successful shots (hits). The mean fixation duration data are presented in Figure 3 (bottom).

Lift Phase Duration

There were no significant main effects for threat, $F(1, 9) = 1.08$, $p = .33$, $\omega^2 = .09$, accuracy, $F(1, 9) = .29$, $p = .60$, $\omega^2 = .05$, or trial, $F(3.9, 35.4) = .97$, $p = .43$. There were no significant interaction effects.

Extension Phase Duration

There were no significant main effects for threat, $F(1, 9) = .81$, $p = .39$, $\omega^2 = .11$, accuracy, $F(1, 9) = .14$, $p = .71$, $\omega^2 = .02$, or trial, $F(9, 81) = 1.59$, $p = .13$. There were no significant interaction effects. The lift and extension movement phase data are presented in Table 1.

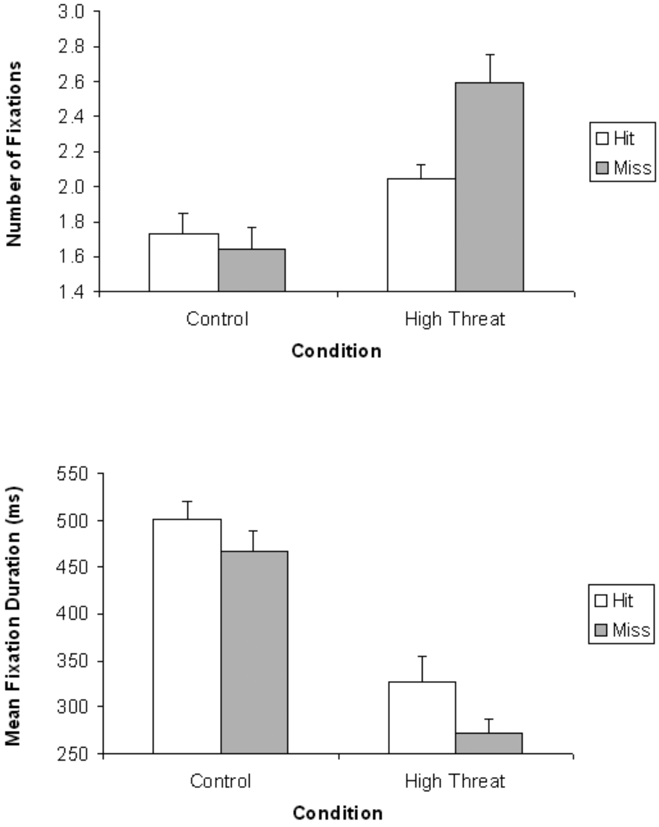

Figure 3 — Fixation data: Mean number of fixations (top) and duration (ms; bottom) for successful (hits) and unsuccessful (misses) shots, during control and high threat conditions (with standard error bars).

Table 1 Mean (*SD*) Movement Phase Durations for Successful (Hit) and Unsuccessful (Miss) Shots, During Control and High-Threat Conditions

	Control		**High Threat**	
	Hit	**Miss**	**Hit**	**Miss**
Lift Phase (in milliseconds)	869.0 (317.16)	868.0 (302.51)	828.8 (269.42)	847.2 (280.80)
Extension Phase (in milliseconds)	247.0 (74.61)	246.9 (78.42)	239.6 (55.87)	235.5 (64.04)

Discussion

This study aimed to test the predictions of the recently developed attentional control theory (ACT; Eysenck et al., 2007), using gaze behavior measures frequently adopted in the sport psychology and motor control literature. While ACT was developed to examine the effects of anxiety on cognitive tasks, it is clear that attentional control is also a key component in the successful performance of visuomotor tasks. As Janelle (2002) highlights, "Given the heavy reliance on visual input for decision making and response planning in sport tasks, logical questions concern whether and how visual attention is modified under increased anxiety" (p. 237). Attentional control theory may therefore provide a framework by which anxiety's effect on visual attention and subsequent performance be better understood.

State Anxiety

Notwithstanding concerns regarding the efficacy of artificially manipulating cognitive state anxiety in laboratory-based studies (e.g., Williams, Vickers, et al., 2002), the cognitive state anxiety data supports the effectiveness of the experimental manipulation in elevating worry. Participants reported higher levels of cognitive anxiety in the high threat as opposed to control condition. A similar pattern was found for somatic anxiety, while participants reported feeling significantly less confident in the high threat as opposed to control condition. A limitation of the study is that participants were not asked to report their potentially changing anxiety levels at more frequent durations (e.g., before each pair of free throw completions). However, by recording anxiety levels *during*, as opposed to just before each testing condition, the mean value determined at least reflects any changes in anxiety levels over time (see also Wilson, Smith, et al., 2007).

Gaze Behavior

The primary measure of gaze behavior adopted in this study was the quiet eye period (Vickers, 1996). This final fixation on the target has previously been shown to be indicative of superior performance in basketball free throws (Harle & Vickers, 2001; Vickers, 1996) and jump shots (Oudejans, Koedijker, Bleijendaal & Bakker, 2005). The results from the current study support these previous research findings in that participants displayed both a longer duration and earlier onset of quiet eye periods during successful shots (hits) as opposed to unsuccessful shots (misses), across both conditions (see Figure 2). The quiet eye durations found in the current study (of around half a second) are also of a similar magnitude to those discussed by Harle and Vickers (2001) and Vickers (2007). This provides support for the procedures used to determine the quiet eye period in the current study, and suggests that the quiet eye has a relatively stable optimal duration for each aiming task.

In a similar manner as reported by Behan and Wilson (2008), the duration of the quiet eye period in the current study reduced significantly (by 34%) in the high-threat compared with control condition. As there were no significant differences in when participants initiated the onset of the quiet eye period in each condition (Figure 2, bottom), this reduction is clearly due to this key fixation being disrupted earlier in the high-threat than control condition. This reduction in quiet eye duration reflects an impairment of attentional control in terms of the mechanisms highlighted by Eysenck et al. (2007); longer quiet eye periods allow performers an extended duration of programming (goal-directed control), while minimizing distraction from other environmental cues (stimulus-driven control). The shorter quiet eye periods in the high-threat condition therefore reflect the disruption caused by anxiety to these functions, as there appears to be an increased influence of the stimulus-driven attentional system at the cost of goal-directed control.

Support for an increased influence of stimulus-driven attentional control is reinforced by the fixation data, which shows that there was an increase in the total number of fixations made, and a decrease in their mean duration (Figure 3). This data suggests that rather than maintaining a fixation on a single target (the quiet eye), participants directed their gaze to a number of targets in the vicinity of the hoop for shorter periods. Vickers's (1996) seminal study of gaze behavior in basketball free throw shooting demonstrated that better players controlled their gaze to a smaller area (they focused on one specific target point) and had a lower frequency of fixations during each shot (they maintained this "quiet eye period") than less skilled counterparts. The players in the current study are therefore using a less efficient and effective attentional control strategy when anxious; they initiate an optimal quiet eye fixation but fail to maintain it.

As ACT is a relatively recent theoretical development, there are few published studies in the mainstream cognitive psychology literature that might support the findings reported in the current study. However, Derakshan, Ansari, Hansard, Shoker, and Eysenck (2009) have examined the effects of anxiety on the inhibitory function of the central executive using an anti-saccade task. In this task, participants are presented with an abrupt peripheral stimulus to one side of a central fixation point and are instructed not to look at the stimulus but to direct their gaze as quickly as possible to the other side of the fixation point. Correct performance in this task requires top-down attentional processes to suppress a reflexive saccade toward the abrupt peripheral stimulus (i.e., inhibit) and simultaneously generate a saccade to its mirror position as fast as possible. The results showed that high-anxious participants had a slower first correct saccade (i.e., to the mirror position) than low-anxious participants, demonstrating less efficient attention control. While Derakshan and colleagues' study supports the predictions of ACT with regards external irrelevant stimuli, the current study demonstrates that distracting internal stimuli (increased worrisome thoughts) may also impair the inhibition function and subsequent attentional control.

Performance

Attentional control theory (ACT), like its predecessor processing efficiency theory (PET), predicts that anxiety will have a greater impact on processing efficiency than performance effectiveness. Theoretically therefore, reduced processing efficiency caused by the disruption to the inhibition function of the central executive will not necessarily lead to decrements in performance. However, based on the findings of the two previous studies to examine the influence of anxiety on quiet eye (Behan & Wilson, 2008; Vickers & Williams, 2007) it is clear that performance is likely to be affected if the disruption to the quiet eye period is significant. Quiet eye durations in the current study were reduced by 34% between control and high-threat conditions, whereas performance accuracy reduced by 26%. In the current study, anxiety negatively impaired both the measures of attentional control and performance effectiveness.

The participating players were not elite free throw shooters based on Harle and Vickers's (2001) definition of free throw shooting percentages above 75%. However, their percentage shooting accuracy figures are similar to those of Harle and Vickers's "near elite" group. The findings of the current study therefore suggest that the influence of anxiety on performance, through impairments in attentional control (quiet eye), is not just an issue for elite performers (cf. Vickers and Williams's [2007] findings for elite biathletes), but for lower level performers too.

A possible concern with our interpretation of the control and high-threat condition results is that the familiarization condition performance (53.5%) is similar to that in the high-threat condition (50.5%), but much lower than control condition performance (68.6%). Generally, it would be expected that familiarization and control condition performance should be similar and reflective of a baseline performance level. However, poor familiarization condition performance in the current study is likely due to a degree of familiarization and habituation with the particular laboratory environment and wearing of the eye tracker. As these performers were not elite, a degree of fine tuning could be expected during such a habituation period. Furthermore, as the mean performance values are derived from a smaller sample in the familiarization condition (10 shots in each phase) than the control condition (mean of 26.8 shots, *SD* = 6.21), any habituation effects will have been exaggerated. Since the order of the test conditions (control and high threat) was counterbalanced, the higher performance levels found in the control condition cannot be explained by learning effects. We therefore suggest that the control, not familiarization, condition is reflective of baseline performance, and the poorer high-threat condition performance caused by disruptions to attentional control, as predicted by ACT.

Implications

Janelle (2002) has previously suggested that attentional control is one of the most critical psychological skills to perform effectively in sports. Studies like the current one help further our understanding of how attentional control and skilled performance might break down under pressure. Previous research by Vickers and colleagues has already demonstrated that performers can be taught to develop a longer and earlier quiet eye period, with subsequent improvements to performance. For example, Harle and Vickers (2001) found that quiet eye training improved the free throw performance of female university basketball players in both a laboratory environment and during match-play.

The current findings would suggest that such training programs may also be a useful intervention to enhance attentional control in stressful environments, perhaps as part of a suitably developed pre-shot routine (e.g., see Wilson & Richards, in press). By actively maintaining an effective quiet eye period, the negative effects of anxiety on visual attentional control and subsequent performance may be alleviated. More research is therefore required to examine the influence of anxiety on the quiet eye and other measures of attentional control (Wilson, 2008).

From a theoretical perspective, it is clear that ACT provides a useful framework by which visual attentional control in stressful environments can be examined. To date there have been few studies even in the cognitive psychology literature which have tested its main predictions (Derakshan & Eysenck, in press; Derakshan et al., 2009). It is possible therefore, that cognitive sport psychologists, with their experience of analyzing gaze behavior, may take the lead in the testing of the predictions of ACT in more applied settings (e.g., Nieuwenhuys et al., 2008).

Conclusions

The purpose of the study was to test the predictions of ACT, using the quiet eye period as an objective and well understood index of attentional control. As predicted, anxiety caused reduced quiet eye periods, possibly due to an impairment of the inhibition function of the central executive and an increased influence of stimulus-driven attentional control. Support for increased impairment of inhibition was provided by the fixation behavior data, which demonstrated that rather than maintaining a long fixation on a single target area (quiet eye) participants directed their gaze to more target locations in the vicinity of the hoop for shorter durations. The findings therefore provide support for the predictions of ACT and suggest that the negative influence of anxiety on performance is likely due to disruptions in attentional control.

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