The effect of anxiety on anticipation, allocation of attentional resources, and visual search behaviours

Abstract

We examine the effect of skill level on the ability to mediate the effects of high anxiety on anticipation and the capacity to allocate attentional resources to concurrent tasks in the sport of badminton. We employed a repeated measures design with counterbalanced anxiety conditions. Skilled and novice badminton players completed an anticipation test in which they predicted serve direction under high- and low-anxiety conditions. On selected trials, participants completed an auditory secondary task. Visual search data were recorded. The Mental Readiness Form v-3 was used to measure cognitive and somatic anxiety and self-confidence. The Rating Scale of Mental Effort was used to measure mental effort. Skilled players outperformed novices on the anticipation task across both anxiety conditions. However, both groups decreased anticipation performance under high- compared to low-anxiety. High-anxiety resulted in an increase in mental effort and a decrease in final fixation duration for both groups when compared to low-anxiety. Anxiety had a negative impact on secondary task performance for the novice, but not the skilled group. High-anxiety was shown to negatively impact anticipation performance regardless of expertise level. However, skilled athletes can more effectively allocate attentional resources during performance under high-anxiety conditions. In contrast, novice athletes utilise a greater amount of attentional resources completing the primary task and, therefore, are unable to maintain secondary task performance under high-anxiety.

Key Words: skill acquisition; perceptual-cognitive skill; expert performance

The effects of anxiety on anticipatory performance, allocation of attentional resources and visual search behaviours in skilled and novice badminton players

Sports performance can be negatively affected by a number of variables, such as anxiety (e.g., Causer, Holmes, Smith & Williams, 2011), fatigue (e.g., Reilly, Drust, & Clarke, 2008) and injury (e.g., Robbins & Waked, 1998). Anxiety is defined as “an aversive motivational state that occurs in threatening situations” (Eysenck, Derakshan, Santos, & Calvo, 2007, p. 336). It can influence various components of performance including anticipation judgements and decision making (Williams & Elliott, 1999). It is reported that expert athletes are thought to be able to reduce the detrimental effects of high-anxiety on performance, possibly by allocation of greater attentional resources to the task (Nibbeling, Oudejans, & Daanen, 2012), reinforcing goal-directed visual search strategies (Wilson et al., 2007) and inhibiting the feelings of anxiety (Page et al., 1999) . However, only a limited number of researchers have investigated the role of skill level in mediating the ability to allocate attentional resources and maintain performance under anxious conditions. We examine this issue using groups of skilled and novice badminton players who attempt to anticipate opponent actions when viewing filmed stimuli under high- and low-anxiety conditions.

High-anxiety has been shown to decrease performance in many sports and across skill levels including the anticipation of karate moves by expert and novice martial artists (Williams & Elliott, 1999), basketball free throwing by intermediate level players (Wilson, Vine, & Wood**,** 2009a), and skeet shooting at the elite level (e.g., Causer et al., 2011). The sport of badminton has also received a significant amount of attention (Alder et al., 2014; Alder, Ford Causer & Williams, 2016; Duncan, Chan, Clarke, Cox & Smith, 2016) with researchers examining a variety of expertise levels (novice vs skilled), tasks (serve, smash) and stressors (anxiety, fatigue). The work has consistently highlighted the effects for expertise (i.e. Alder et al., 2014), anxiety and fatigue (Duncan et al., 2016) and the ability to improve decision making performance through perceptual-cognitive training (Alder et al., 2016).

Attentional control theory (ACT; Eysenck et al., 2007) provides an explanatory account of the mechanisms by which anxiety affects performance. ACT articulates the impact anxiety has on performance and the differences between performance outcome and processing efficiency. Processing efficiency can be measured through changes in mental effort (e.g., Wilson et al., 2007) and visual search behaviours (Causer et al., 2011; Williams & Elliot, 1998; Wilson et al., 2009a; Wilson, Wood & Vine, 2009b). Performance efficiency may be calculated by dividing the outcome by the processing resources invested in the task. Under high-anxiety conditions, individuals are thought to allocate attentional resources to locating and negating the source of the threat, which increases mental effort, causing a decrease in performance efficiency in an effort to maintain performance outcome (Derekshan & Eysenck, 2009). For example, Vater and colleagues (2016) describe how when anticipating opponent actions in a temporally occluded 11 v 11 soccer test, high-anxiety negatively influenced the processing efficiency (as evidenced through increased response times and mental effort) of both skilled and less-skilled participants when compared to low-anxiety conditions. However the effectiveness of performance (i.e. response accuracy) remained unaffected across anxiety conditions.

As well as the proposed reduction in processing efficiency, ACT describes how anxiety alters the contributions of two types of attentional control within working memory, namely the goal-directed and stimulus-driven systems (Baddeley & Hitch, 1974). The *goal-directed system* is involved in cognitive control of visual attention and responses, and is influenced by current goals, expectations, and knowledge. The *stimulus-driven system* is recruited for the detection and direction of attention to relevant, salient or conspicuous events (Corbetta & Shulman, 2002). Wilson and colleagues (2009) presented evidence supporting this shift in attentional control from the goal-directed to stimuli-driven system. These authors examined how experienced soccer players executed penalty kicks under high and low-anxiety conditions. In the high-anxiety condition, they fixated for longer durations on the goalkeeper, indicating recruitment of stimulus-driven control, and shorter durations on the target area, demonstrating a decrease in goal-directed focus, when compared to the low-anxiety condition. The decrease in visual attention toward goal-directed sources was accompanied by a decrement in shooting performance.

Nieuwenhuys and Oudejans (2012) built upon the earlier work of ACT by proposing how attentional control is impaired at both a global and local level. They articulate how the ability of an individual to correctly interpret information emanating from visual cues is impaired under high-anxiety - thus individuals may be attending to task-relevant cues (i.e. remaining Goal-directed) but are unable to perceive key information sources correctly. For example, Correll et al., (2002) identified that policeman who were highly anxious of being shot by a suspect were more likely to misinterpret whether or not a suspect was in possession of a gun or not compared to those who were not as anxious about being shot. The model describes how anxiety leads to a reduction in the efficiency of performance in order to maintain the outcome or effectiveness (Eysenck et al., 2007). One way in which this reduction in efficiency manifests itself is through an increase in mental and/or physical effort (Wilson et al., 2007)**.** Wilson et al. (2007) demonstrated this with intermediate-level golfers tasked with completing a series of putts across anxiety conditions. Absolute putt error (i.e. performance outcome) did not differ between high- and low-anxiety conditions for players categorised as low-trait anxiety, but deteriorated for players who were high-trait anxiety. In the high-anxiety condition, the golfers reported greater mental effort and a decrease in the efficiency of their visual search when compared to the low-anxiety condition, demonstrating that processing efficiency is reduced under high- compared to low-anxiety conditions.

Nieuwenhuys and Oudejans (2012) argue that the increase in effort that accompanies high-anxiety can be allocated to a range of areas within working memory. First, the additional effort may be directed to reduce the feelings of anxiety. For example, an athlete experiencing anxiety could use pre-determined imagery techniques and breathing strategies to reduce the feelings of anxiety prior to performance (i.e. Page et al., 1999). Second, the additional effort may be directed to reinforcing goal-directed attentional strategies. Previously, researchers have shown how visual search training (e.g. Wilson et al., 2011), in which participants are provided with information relating to gold standard gaze behaviour, can be effective in controlling the impact of anxiety on attentional control. Furthermore, placing individuals into pressurised situations in training that are congruent to those in performance has also been show to result in improved attentional control (see Alder et al., 2016). It is postulated that when the additional mental effort that is invested is not sufficient to counter the negative effect of anxiety, attention may shift to negatively impact on performance (Eysenck et al., 2007).

The effect of anxiety on performance outcome and processing efficiency may further be related to the expertise level of participants (Nibbeling et al., 2012). It is hypothesised that as expertise level increases, so does the ability to better control the detrimental effects of anxiety on performance (Williams & Elliott, 1999). It is thought that experts have domain-specific knowledge structures that result in tasks being completed with fewer demands on working memory (Ericsson & Kintsch, 1995). These lower demands on working memory allow expert athletes to redistribute attentional resources elsewhere, such as when experiencing high-anxiety. In contrast, novices do not have sophisticated domain-specific knowledge structures. Therefore, the high demands of the primary task on working memory do not allow them to redistribute attentional resources under high-anxiety conditions, possibly resulting in decrements to performance outcome when the demands become too great.

In one of the few studies to examine the effects of anxiety on performance outcome and processing efficiency as a function of skill level, Nibbeling et al. (2012) asked skilled and novice darts players to complete a darts throwing task under high- and low-anxiety conditions while carrying out a secondary task of backwards counting. In the high-anxiety condition, primary task performance was worse for the novice group, but not the skilled group, when compared to the low-anxiety condition. Secondary task performance significantly decreased for both groups in the high- compared to low-anxiety condition. Both groups demonstrated the predicted decrease in processing efficiency through less efficient visual search strategies and greater mental effort under high- compared to low-anxiety conditions. Data for the novice group suggests that when mental effort becomes too high and a shift occurs from goal-directed to stimulus-driven attentional control, then a decrement in performance outcome will occur (Eysenck et al., 2007; Nieuwenhuys & Oudejans, 2012). Data for the skilled group supports the processing efficiency prediction by showing that under high-anxiety conditions performance outcome can be maintained by sacrificing processing efficiency.

In similar vein, Cocks et al. (2016) reported comparable findings in a study in which skilled and less-skilled tennis players anticipated opponent actions across a number of contextual information conditions. The skilled players were able to maintain a superior level of performance effectiveness under high-anxiety conditions when compared to less-skilled players. Yet, processing efficiency for the skilled group in the high-anxiety condition was significantly reduced compared to the low-anxiety condition, suggesting that for skilled players a reduction in processing efficiency can compensate for additional anxiety in order to negate the effects on performance effectiveness.

More effective visual search strategies have been shown to underpin successful completion of *perceptual-motor* skills by skilled participants under high- compared to low-anxiety conditions (Nibbeling et al. 2012). However, researchers are yet to show how these findings extend to anticipation and decision making. Anticipation is the ability to predict an upcoming action prior to its completion (Williams, Ford, Eccles & Ward, 2011), and it can be negatively affected by high-anxiety conditions (e.g., Williams & Elliott, 1999). There is a lack of research investigating the role of skill level on the ability to effectively distribute attentional resources during these judgements. Moreover, high-anxiety usually leads to decrements in performance on sports tasks (e.g., Causer et al., 2011; Williams & Elliott, 1999), Wilson, et al., 2009a). The inclusion of secondary tasks in studies (Nibbeling et al. 2012; Runswick et al., in press) examining the distribution of attentional resources has led to the contradictory finding that participants *maintain* primary task performance under high- compared to low-anxiety conditions. Therefore, there is a need to re-examine how participants divide attention under high-anxiety conditions to address these contradictory findings.

We investigate the ability of skilled and novice badminton players to make anticipatory judgements and allocate attentional resources under high- and low-anxiety conditions. Participants complete a temporal occlusion anticipation test under counterbalanced anxiety conditions. On selected trials, participants completed an auditory tone monitoring secondary task. Skilled participants were expected to make more accurate anticipatory judgements compared to their novice counterparts in both anxiety conditions. Both groups were expected to experience a decrease in anticipation judgement accuracy performance outcome in the high- compared to the low-anxiety condition. Processing efficiency was predicted to reduce under high-anxiety conditions for both groups compared to the low-anxiety condition, with these effects being more pronounced in novice compared to skilled athletes (Nibbeling et al., 2012). Processing efficiency decreases would be evidenced through an increase in both mental effort and the number of visual fixations employed, and a decrease in mean duration of fixation and/or decreased secondary task performance.

Materials and methods

Participants

Participants were 10 skilled professional badminton players (*M* = 20 years of age, *SD* = 4) and 10 novice badminton players (*M* = 22 years of age, *SD* = 2). Skilled players had accumulated an average of 13 years (*SD* = 2.4) experience in competition. They were taking part in at least 20 hours a week of badminton practice at the time of the study and had played county standard for a minimum of five years in the United Kingdom. Novice participants had not taken part in any structured badminton training or competition. Participants gave their informed consent prior to the study. The local ethics committee provided full ethical approval.

Task and apparatus

A temporal occlusion test film task was created involving badminton serves in a doubles match. Four expert badminton players of international standard were filmed completing a variety of serves from the first person perspective of their opponent in a doubles match. A high-definition (HD) video camera (Canon XHA1S; Tokyo, Japan) was positioned two metres away from the net at eye level (1.7 metres). The four players completed three serves to each of six different locations on their opponent's side of the court. The locations were unanimously identified by the panel of three international coaches as being the most commonly used during serves in a badminton doubles match. The six locations were short tee (the point at which the centre line met the service line), short centre, short wide, long tee (the point at which the centre line met the back tramline), long centre and long wide. During filming, another individual was positioned on court to act as the doubles partner for the server. Both the server and their partner could be viewed on the video footage. Each serve on the footage was edited (Adobe Premier Pro Editing Software, Version CS5, San Jose, USA) into a video clip to be used as a trial in the temporal occlusion test film. The film contained each of the four servers performing 18 serves comprising three serves to each of the six locations, which were distributed in a random order across the 72 trials or serves in total. Occlusion points were created to match previous research on anticipation so that clips were occluded 40 ms prior, 40 ms after and at shuttle/racket contact (Abernethy, 1990). The three occlusion conditions were each presented 24 times across the 72 trials, and they were equally distributed across trials as a function of the six shot locations.

The test film was back-projected life-size onto a two-dimensional screen (size 2.74 metres high x 3.66 metres wide, Draper, USA). The screen was positioned on the opposite side of a full-size international standard badminton court, 1.98 metres from where the net would be, in a position that provided the most representative view of the serves. Participants were required to start each trial on either the left or right hand side of the service area as they would in a normal badminton match. The start locations were marked with an "X" using tape. Each video clip began with a black screen for 2,000 ms containing white text informing the participant to stand in the left or right service box so as to receive the on screen serve. At 2,000 ms, a black screen showed white text of a "3, 2, 1" countdown that lasted 3,000 ms. At 5,000 ms, a still picture of the initial video frame of the service action was shown for 1,000 ms. At 6,000 ms, the video clip began playing and the duration of each clip was approximately 3,000 ms. Each clip ended with a black screen that occluded the video and lasted for 3,000 ms.

Participants were required to anticipate the end location of the serve by moving to complete a shadow shot and then verbalising their response. If there was a discrepancy between the movement and the verbalised response, the trial was classified as incorrect. The physical shadow return shot was not recorded as a dependent variable, but was used to increase the fidelity of the task. If a participant had not verbalised their answer and completed the shadow return shot by the time the still image for the next trial appeared (i.e. 3,000 ms), the trial was deemed incorrect. No trials were recorded as being inaccurate for the above reasons. The test sessions were recorded using a high-definition (HD) video camera (Canon XHA1S; Tokyo, Japan), which was positioned two metres perpendicular to the service line. The video footage was analysed using Dartfish 4.5.2.0 (Dartfish, Fribourg, Switzerland) Software with a frequency of 50 Hz providing an accuracy of 40ms/frame. The first movement made by the participants was used as the dependent variable. This was identified as the first frame when there was an "observable and significant lateral motion – right or left – of the racket, the hips, the shoulder or the feet, which was made in order to move to the future location of the next strike" (Triolet et al., 2013, p.822). A correct response corresponded to an initial movement that orients in the same direction as the shuttle direction, while an incorrect response referred to a movement in the opposite direction to where the shuttle was directed. The experimenter hand notated the verbal responses during the experiment.

A secondary task was added to the test film, which consisted of high (n = 18) and low (n = 18) frequency tones, therefore 50 % of trials (n = 36 trials) featured a tone. High tones were 2,500 Hz whereas low tones were 300 Hz. These trials were balanced across occlusion condition. This therefore led to each occlusion condition containing six high and six low tones. The tones were presented in such a way that their onset could not be predicted. The tones played between 500 and 700 ms into the video clip and were presented in a random order, but kept the same for each participant. Catch trials were used in which either a low tone (n = 18 trials) or no tone (n = 36 trials) were presented in order to make the secondary-task unpredictable. Participants held a badminton racket through the experiment, with a push-to-make switch attached to the handle to fit a traditional grip. On high tone trials participants were instructed to press the button as quickly as possible, whereas on low tone trials they were instructed not to respond. The button was connected to a desktop computer through a cable and synchronised with a developed algorithm through the numerical computing environment MATLAB (Mathworks R2007, UK). The algorithm enabled the onset of the high tones and the moment the participant pressed the button to be recorded and analysed, providing a measure of reaction time for the secondary task.

Procedure

The experiment consisted of high- and low-anxiety testing conditions, the order of which was counterbalanced across participants. In total, there were 72 clips or trials per anxiety condition. In order to limit the potential for learning effects, the trials were randomised in order to create two different test films, which were counterbalanced across participants and anxiety conditions. Prior to the experiment, participants received instruction about the rationale and protocol of the study. They took part in 10 familiarisation trials of the temporal occlusion anticipation task prior to starting the experiment.

The level of anxiety experienced by participants during the sessions was manipulated across two separate test sessions using a previously developed protocol (Wilson et al., 2008). In the low-anxiety session, a neutral statement was read to the participants at the start of the session informing them that their performance was to be used for research purposes only and that there would be no consequences for poor performance or comparison to peers. In the high-anxiety session, participants were read an anxiety inducing statement at the start of the session in which they were instructed that their performance was being filmed and analysed. The skilled group were informed feedback would be provided to their coach and that their performance was to be ranked against their peers, whereas the novice group were instructed they were to be ranked against individuals of similar skill-level and results shown on a notice board. Once the familiarisation trials had finished, regardless of performance, participants in the high-anxiety condition were informed their performance was unsatisfactory and they were to start the test again. Participants were then presented with and interacted with the test film task.

To measure the manipulation of anxiety, participants completed the Mental Readiness Form, version 3 (MRF-3; Krane, 1994). The MRF-3 is a tool used for measuring state anxiety. It has three bipolar 11-point Likert scales that consist of *worried* and *not worried*, *tense* and *not tense* and, finally, *confident* and *not confident*. The MRF-3 was completed after the familiarisation trials in the low-anxiety condition and after the anxiety inducing statement that followed the familiarisation trials in the high-anxiety condition. At the end of both anxiety conditions, participants completed the Rating Scale of Mental Effort (RSME; Zijlstra, 1993). The RSME is a scale ranging from 0-150 with higher scores indicating greater mental effort.

A mobile eye-tracking system (ASL MobileEye, Bedford, USA) was used to record gaze behaviours. The head-mounted monocular eye-tracking system computes point of gaze within a scene through calculation of the vector between pupil and cornea. The calibration consisted of participants fixating six pre-determined locations on a still image of one of the trials (opponent's head and left foot, non-server's head, shuttle, and racket head). During calibration, participants were instructed to adopt the typical stance used when returning serve. The calibration of the eye tracking system was checked after the familiarisation trials.

Data analysis

Response accuracy on the primary anticipation task was determined by awarding a correct response for the initial movement that oriented in the same direction as the shuttle direction, while an incorrect response referred to a movement in the opposite direction to where the shuttle was directed. Response time on the secondary task was calculated by determining the difference between the onset of the high tones on each trial and the moment when the button on the racket was pressed. The analysis was conducted through MATLAB with the software extrapolating all the data points over 4 volts for the button press response. Response accuracy on the primary task was analysed using a 2 Group (Skilled, Novice) x 2

Anxiety Condition (High, Low) ANOVA. Response time on the secondary task and RSME were analysed separately in 2 Group x 2 Anxiety Condition ANOVAs. Data from each subscale from the MRF-3 were analysed via using separate 2 Group (Skilled, Novice) x 2 Anxiety Condition (Low, High) ANOVAs. The eye movement data were recorded at 25 frames per second with the film footage being subjected to frame-by-frame analysis using video editing software (Adobe Premier Pro Video Editing Software, Version CS 5, San Jose, USA). A fixation was recorded when gaze remained within three degrees of visual angle upon a location for a minimum of 120 ms (Vickers, 1996). Final fixation was defined as the last fixation on the screen prior to the video occluding. The test film used as the primary task in this study, as well as the eye movement analyses procedures, were the same as in Alder et al. (2014). The servers' action involved a preparation phase, defined as starting at the frame in which the server established their stance by planting their feet (M = 3,400 ms, SD = 500), and an execution phase, defined as starting from the frame containing the point at which the racket and shuttle are brought together in a "set position" in front of the body up to the frame containing racket-shuttle contact (M = 1,900 ms, SD = 500). The movement time from the start of the preparation phase to the occlusion point was a mean of 4,300 ms. The analyses of eye movements was conducted from the start of the preparation phase of the movement to the occlusion of the video in Alder et al. (2014). Alder et al. reported no between- or within-group differences for fixation location during the preparation phase of the movement, whereas during the execution phase there were expertise and response success main effects and interactions. Given that the duration of the execution phase of the servers' movement is similar to the duration of final fixation, such that the penultimate fixation likely occurs in the preparation phase where no differences were found in Alder et al., in the current study only the location of final fixation was analysed.

The number of fixations per trial and mean duration of fixations was calculated. Separate 2 Group (Skilled, Novice) x 2 Anxiety Condition (High, Low) ANOVAs were used to analyse the number of fixations per trial, mean duration of fixation, and the mean duration of final fixation. Final fixation location categories were chosen to match those from Alder et al. (2014): racket; wrist; shuttle; head and other. To examine the effect of anxiety and expertise on the final fixation location, a 2 Group (Skilled, Novice) x 2 Anxiety Condition (Low, High) x 5 Location (Racket, Wrist, Shuttle, Head, Other) ANOVA was used with location of fixation being the dependent variable. Intra-reliability observer checks were conducted on the visual search data using the test-retest method (Thomas, Nelson, & Silverman, 2005), with data from one skilled (97% reliable) and one novice participant (96% reliable) being re-analysed.

For all ANOVA analyses, violations of the assumption of sphericity were corrected using the Greenhouse-Geisser method. Any significant interactions were analysed using Tukey's Honestly Significant Difference, whereas Bonferroni comparisons were used for main effects involving more than two variables. Partial eta squared (η_p^2) was used to represent effect sizes and confidence intervals are presented. For all statistical tests, the alpha level for significance was .05.

Results

Anxiety manipulation

Table 1 shows the descriptive statistics for the responses to the MRF-3 for both groups across anxiety conditions. Each ANOVA revealed significant main effects of Anxiety Condition; with participants reporting significantly higher values in the high- compared to the low-anxiety condition (Cognitive subscale; $F(1, 18) = 33.89$, $p < .02$¸ $\eta_p^2 = .65$, Somatic subscale; $F(1, 18) = 21.21$, $p < .02$¸ $\eta_p^2 = .54$, Self-confidence; $F(1, 18) = 25.26$, $p < .02$¸ $\eta_p^2 = .58$). There were no Group main effects on any of the ANOVA (Cognitive subscale; F (1,

18) = 2.77, p = .11¸ η_p^2 = .13, Somatic subscale; F (1, 18) = 4.19, p = .06¸ η_p^2 = .19, Self-confidence; F (1, 18) = 1.21, p < .82¸ η_p^2 = .02) nor any Group x Anxiety condition interactions (Cognitive subscale; F (1, 18) = 1.01, p = .76¸ η_p^2 = .03, Somatic subscale; F (1, 18) = 0.07, p = .80¸ η_p^2 = .01, Self-confidence; F (1, 18) = 0.19, p < .67¸ η_p^2 = .01.

Mental effort

For RSME, ANOVA revealed the main effect for anxiety approached significance, *F* (1, 18) = 3.18, *p* = .09, η_p^2 = .15). Participants reported greater mental effort in the high- (*M* = 86, *SD* = 4) compared to low-anxiety condition (*M* = 71, *SD* = 5). There was no group main effect, *F* (1, 18) = < .01, *p* = .97, η_p^2 < .01, or Group x Anxiety interaction, *F* (1, 18) = 0.19, *p* = .66, η_p^2 = .01.

Primary task anticipation performance

Figure 1 shows the response accuracy scores of both groups on the anticipation test across the high- and low-anxiety conditions. ANOVA revealed a significant main effect for group, *F* (1, 18) = 41.51, *p* < .01, η_p^2 = .70. The skilled group responded more accurately (*M* = 50 correct trials out of 72 trials, *SD* = 6), when compared to the novice group (*M* = 33 correct trials out of 72 trials, *SD* = 8). There was a significant main effect for anxiety condition, *F* (1, 18) = 4.81, *p* = .04, η_p^2 = .21. Anticipation performance was significantly more accurate in the low- (*M* = 43 trials, *SD* = 10) compared to high-anxiety condition (*M* = 40 correct trials, *SD* = 12). The Group x Anxiety interaction was not significant, *F* (1, 18) = 0.22, *p* = .65, η_p^2 = .01.

Secondary task performance

Figure 2 shows response times (ms) for both groups on the secondary task across the two anxiety conditions. There was a main effect for group, *F* (1, 18) = 2.31, *p* = .02, η_p^2 = .27. Response time was faster for the skilled group (*M* = 416 ms, *SD* = 110) compared to the novice group (*M* = 498 ms, *SD* = 69). There was no main effect for Anxiety Condition, *F* (1, 18) = 2.31, *p* = .15, η_p^2 = .11. There was a significant Group x Anxiety Condition interaction, *F* (1, 18) = 6.45, $p = .02$, $\eta_p^2 = .27$. *Post hoc* tests showed that in the low-anxiety condition, the response time of the skilled group (*M* = 428 ms, *SD* = 105) was not different compared to the novice group (*M* = 451 ms, *SD* = 53). However, in the high-anxiety condition, the skilled group had a significantly faster response time (*M* = 405 ms, *SD* = 119) compared to the novice group (*M* = 545 ms, *SD* = 49). The novice group had significantly slower response times in the high- compared to low-anxiety condition, whereas there was no difference in response time between anxiety conditions for the skilled group.

Visual search behaviour

ANOVA revealed no significant main effects or interactions for number of fixations or the mean duration of fixation (for descriptive statistics, see Table 2). For the mean duration of final fixation, there was a group main effect, *F* (1, 18) = 49.34, $p < .01$, $\eta_p^2 = .73$). The final fixation for the skilled group was significantly longer compared to the novice group (*M* = 1,187 ms, *SD* = 195). There was a main effect for anxiety condition, *F* (1, 18) = 23.19, $p < .01$, $\eta_p^2 = .56$. Final fixation was significantly shorter in the high- compared to the low-anxiety condition. The Group x Anxiety condition interaction was not significant, *F* (4, 72) = 0.36, $p = .84$, $\eta_p^2 = .02$.

For fixation location, there were no main effects for group or anxiety condition. There was a main effect for the location of final fixation, *F* (4, 72) = 516.35, $p < .01$, $\eta_p^2 = .97$. The racket was the location of the final fixation on a significantly greater proportion of trials (*M* = 49 % of all trials, *SD* = 7), compared to the wrist (*M* = 29 % of all trials, *SD* = 6), shuttle (*M* = 10 % of all trials, *SD* = 3), head (*M* = 7 % of all trials, *SD* = 4), and other location (*M* = 6 % of all trials, *SD* = 6). The wrist was fixated on a significantly greater proportion of trials compared to the shuttle, head and other location. There was no difference between the shuttle, head or other location. The Location x Group interaction was significant, *F* (4, 72) = 13.76, $p < .01$, $\eta_p^2 = .43$. The final fixation of the skilled group was on the racket and wrist in a greater proportion of trials compared to the novice group, whereas the final fixation for the novice group was on the head and other category in a greater proportion of trials compared to the skilled group. There was no significant difference between groups in the proportion of trials that the final fixation was on the shuttle. The three-way Group x Anxiety x Location interaction was not significant, F (4, 72) = 0.36, p = .84, η_p^2 = .02.

Discussion

We examined the ability of skilled and novice badminton players to make anticipation judgements and allocate attentional resources under high- and low-anxiety conditions. As per previous work (Nibbeling et al., 2012; Wilson, Vine, & Wood**,** 2009a), we expected skilled participants to make more accurate anticipation judgements compared to their novice counterparts in both anxiety conditions, thus demonstrating a preservation of performance effectiveness as outlined in ACT (Eysenck et al., 2007). This maintenance of performance effectiveness was predicted to be accompanied by a reduction in processing efficiency across anxiety conditions for both skilled and novice participants. This decrease in efficiency was predicted to be evidenced through a reduction in secondary task performance, a greater number of fixations containing shorter durations, and an increase in mental effort (Wilson et al., 2011). Furthermore, this increase in mental effort was predicted to be directed to either reducing the feelings of anxiety, as evidenced through non-significant difference of scores on the MRF-3 scale (Krane, 1994), or through reinforcing goal-directed strategies, as evidenced through similar visual search behaviour patterns across anxiety conditions (Nieuwenhuys & Oudejans, 2012).

As predicted, the skilled group produced significantly more accurate anticipation judgements on the primary task, when compared to the novice group. The finding supports previous research showing that skilled athletes are superior to novices at anticipating opponent actions (e.g., Williams et al., 2002; 2012). Their greater domain-specific experience allows them to recognise characteristics within the current environment leading to superior response selection when compared to less-skilled athletes, who do not have the same volume, depth or variety of experience or knowledge (Causer, Janelle, Vickers & Williams, 2012). The accuracy of anticipation judgements was reduced in the high- compared to low-anxiety condition for both groups. Data support previous work showing performance outcome can deteriorate for both novice (e.g., Nibbeling et al., 2012) and skilled participants (e.g., Causer et al., 2011) under high- compared to low-anxiety conditions. Related work suggests that processing efficiency would decrease in the high- compared to low-anxiety condition, with this effect being more pronounced in novice compared to skilled participants (Cock et al., 2016Nibbeling et al., 2012). The reduction in processing efficiency was expected to occur through a range of measures. First, an increase in mental effort in high- compared to low-anxiety conditions. As anticipated, participants reported greater mental effort in the high-compared to low-anxiety conditions, showing reduced processing efficiency, although there were no differences between groups. Nieuwenhuys and Oudejans (2012) suggest that this additional effort may be redirected to a range of specific areas of working memory in order to attempt to maintain performance, such as reinforcing goal-directed attentional control. The data for number and duration of fixations support this latter suggestion as there was no differences between high- and low-anxiety conditions for either group. Traditionally, skilled athletes have been shown to use fewer fixations of greater duration compared to less-skilled athletes in similar tasks (Abernethy, 1990; Poliszczuk & Mosakowsk, 2009; Savelsbergh et al., 2002). An increase in anxiety has been shown to result in an increase in the number of fixations coupled with a decrease in fixation duration in some instances (Williams & Elliott, 1999). Our findings suggest that participants directed the additional effort to maintaining goal-directed attentional control. This is further evidenced in the location of final fixation data. We expected that in the high-anxiety condition the location of the final fixation to be positioned more frequently on less relevant (e.g., the head of the server) or threatening sources, as opposed to goal-directed cues (e.g., the racket) (Wilson et al., 2007). In contrast to our predictions, there were no changes in fixation location for either group across the anxiety conditions, suggesting the additional effort was being utilised to reinforce goal-directed strategies.

There appeared to be incongruence between the reductions in performance outcome in high-anxiety for both groups with the maintenance of goal-directed visual search strategies. A possible theoretical explanation for this is that participants may have had issues interpreting the key information emanating from visual cues (Nieuwenhuys & Oudejans, 2012). Both groups were able to anticipate opponent actions more accurately in the low-anxiety compared to high-anxiety condition although the visual search behaviour of both groups did not change between anxiety conditions. It can be postulated therefore that, regardless of expertise level, under high-anxiety participants could not perceive or interpret information correctly thus leading to a decrease in performance.

A secondary and more practical explanation for lack of change in visual search behaviour across anxiety conditions may be attributed to the constraints of the task. The badminton serve has a short movement duration and short phases within the movement (Alder et al., 2014). Therefore, the duration of the task may not have provided sufficient time for the differences in fixations normally found across expertise and anxiety levels to become apparent. However, the final fixation duration for both groups supported predictions, as high-anxiety resulted in shorter final fixation durations for both groups compared with low-anxiety, indicating a reduction in processing efficiency. Findings support Nibbeling et al. (2012) who reported that final fixation duration was shorter for both skilled and novice dart players in high- compared to low-anxiety conditions. It supports previous research (e.g., Behan & Wilson, 2008) showing that high-anxiety decreases both the onset and duration of the final fixation prior to the initiation of the response (i.e., Vickers, 1996), potentially leading to a decrease in performance.

The predicted reduction in processing efficiency was evident in the secondary task performance data. Response times for the novices on the secondary task were slower under high- compared to low-anxiety conditions, implying a significant decrease in processing efficiency. However, the secondary task performance of the skilled players was not different between the high- and low-anxiety conditions. It appears the effect of high-anxiety did not require the full attentional resources of skilled participants, leading to effective allocation of spare resources to successful secondary task performance, albeit at the expense of primary task performance. The skilled group reported higher levels of anxiety compared to the novice group under high-anxiety conditions, perhaps explaining their lack of efficiency in delegating attentional resources to the primary task. In contrast, the novice group appeared to allocate too many attentional resources to negating the anxiety threat, leading to a lack of resources being available for primary and secondary task performance, explaining the reduction in performance for both tasks as evidenced through a decrease in response accuracy (primary task) and response time (secondary task). Findings contradict those reported by Nibbeling et al. (2012) who found that secondary task performance deteriorated under high- compared to low-anxiety conditions for both novice and skilled participants. In their study, the expertise effect as a function of anxiety condition was found for the primary, not secondary task. The differences in anxiety levels experienced or methodological instructions may explain the contradictory findings across studies. A limitation of this study in this regard is that the secondary task was auditory, rather than visual as per Murray and Janelle (2003). It may be that visual secondary tasks lead to greater distractibility from goal-directed cues to less relevant or threatening sensory stimuli. A further limitation of this study relates to the timing of the anxiety measurement. Information relating to anxiety was assessed pre task in both conditions; post familiarisation trials in the low-anxiety and post anxiety inducing statement in the high-anxiety condition. Therefore any changes in levels of anxiety during performance were missed. Furthermore, although the method for developing anxiety has been consistently shown elicit high levels of anxiety (see Alder et al., 2016; Wilson et al., 2007), this may not be truly reflective of the high anxiety conditions experienced by performers in actual competition.

In summary, the anticipation judgements of both groups decreased from high- to low-anxiety conditions, supporting previous research (e.g., Causer et al., 2011). Under high-anxiety conditions, there was a decrease in performance efficiency for both groups, as demonstrated by an increase in mental effort and a decrease in the duration of final fixation. Furthermore, our visual search data support previous work (i.e. Nieuwenhuys & Oudejans, 2012) in that it appears the additional effort reported by both groups was used to maintain a goal-directed strategy, potentially explaining the lack of differences between anxiety conditions. Furthermore, our data suggest that although the visual search strategy was maintained the ability of the participants to correctly interpret the key information emanating from the information rich areas was hampered under high-anxiety. The decrease in secondary task performance for the novice group, but not for the skilled participants, suggests that skilled players required fewer attentional resources to perform the primary task, so that under high-anxiety conditions they were able to allocate attentional resources to both negating the effects of anxiety and maintaining secondary task performance. From an applied perspective, data suggests that regardless of expertise level- anxiety impacts performance and its underpinning mechanisms. Furthermore simply maintaining a consistent visual search behaviour when experiencing anxiety may not be sufficient to maintain performance as the ability of individuals to interpret information emanating from cues may be compromised.

References

Abernethy, B. (1990). Anticipation in squash: Differences in advance cue utilization between expert and novice players. *Journal of Sport Sciences, 8*, 17-34.

Alder, D. B., Ford, P. R., Williams, A. M., & Causer, J. (2016). The Effects of High-and Low-Anxiety Training on the Anticipation Judgments of Elite Performers. *Journal of Sport and Exercise Psychology, 38,* 93-104.

Alder, D., Ford, P. R., Causer, J., & Williams, A. M. (2014). The coupling between gaze behavior and opponent kinematics during anticipation of badminton shots. *Human Movement Science, 37*, 167-179.

Baddeley, A. D., & Hitch, G. J. (1974). Working memory. *The Psychology of Learning and Motivation, 8,* 47-89.

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

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

Causer, J., Janelle, C. M., Vickers, J. N., & Williams, A. M. (2012). Perceptual expertise: What can be trained? In: Hodges, N. J., &Williams, A. M. eds. *Skill acquisition in sport: Research, theory and practice*. London: Routledge. pp 306-324.

Cocks, A.J., Jackson, R.C., Bishop, D.T. and Williams, A.M. (2016) Anxiety, anticipation, and contextual information: A test of Attentional Control Theory. *Cognition and Emotion, 30,* 1037-1048.

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

Correll, J., Park, B., Judd, C. M., & Wittenbrink, B. (2002). The police officer’s dilemma: Using race to disambiguate potentially threatening individuals. *Journal of Personality and Social Psychology*, 83, 1314–1329.

Derakshan, N., & Eysenck, M. W. (2009). Anxiety, processing efficiency, and cognitive performance new developments from attentional control theory. *European Psychologist*, *14*, 168-176.

Derakshan, N., Smyth, S., & Eysenck, M. W. (2009). Effects of state anxiety on performance using a task-switching paradigm: an investigation of attentional control theory. *Psychological Bulletin Review, 16,* 1112-1117.

Duncan, M. J., Chan, C. K., Clarke, N. D., Cox, M., & Smith, M. (2016). The effect of badminton-specific exercise on badminton short-serve performance in competition and practice climates. *European Journal of Sport Science,* 1-8.

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

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

Eysenck, M. W., Payne, S., & Santos, R. (2006). Anxiety and depression: Past, present, and future events. *Cognition & Emotion, 20*, 274-294.

Huys, R., Smeeton, N. J., Hodges, N. J., Beek, P. J., & Williams, A. M. (2008). On the dynamic information underlying visual anticipation skill. *Perception & Psychophysics, 70*, 1217- 1234.

Krane, V. (1994). The Mental Readiness Form as a measure of competitive state anxiety. *The Sport Psychologist, 8*, 89–202

Maracora, S. M., Staiano, W., & Manning, V. (2009). Mental fatigue impairs physical performance in humans. *Journal of Applied Physiology, 106,* 857-864.

Murray, N. P., & Janelle, C. M. (2003). Anxiety and performance: A visual search examination of the Processing Efficiency Theory. *Journal of Sport & Exercise Psychology, 25*, 171-187.

Nibbeling, N., Oudejans, R. R. D., & Daanen, H. A. M. (2012). Effects of anxiety, a cognitive secondary task, and expertise on gaze behaviour and performance in a far aiming task. *Psychology of Sport and Exercise, 13*, 427-435.

Nieuwenhuys, A., & Oudejans, R. R. (2010). Effects of anxiety on handgun shooting behaviour of police officers: A pilot study. *Anxiety, Stress, & Coping*, 23, 225-233.

Nieuwenhuys, A., & Oudejans, R. R. (2012). Anxiety and perceptual-motor performance: toward an integrated model of concepts, mechanisms, and processes. *Psychological Research, 76*, 747-759.

Oudejans, R. R. D., & Pijpers, J. R. (2010). Training with mild anxiety may prevent choking under higher levels of anxiety. *Psychology of Sport and Exercise, 11,* 44-50.

Page, S. J., Sime, W., & Nordell, K. (1999). The effects of imagery on female college swimmers' perceptions of anxiety. *The Sport Psychologist*, 13, 458-469.

Poliszczuk, T., & Mosakowsk, M. (2009). Inter-reactions of peripheral perception and ability of time-movement anticipation in high class competitive badminton players. *Studies in Physical Culture and Tourism, 16,* 259-265.

Reilly, T., Drust, B., & Clarke, N. (2008). Muscle fatigue during football match-play. *Sports Medicine*, *38*, 357-367.

Robbins, S., & Waked, E. (1998). Factors associated with ankle injuries. *Sports Medicine*, *25*, 63-72.

Runswick., O., Roca, A., Bezodis, N.E., Williams, A.M. and North, J.S. (in press) The effects of anxiety and situation-specific context on perceptual-motor skill: A multi-level investigation. *Psychological Research.*

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

Thomas, J. R., Nelson, J. K., & Silverman, S. J. (2005). *Research methods in physical activity (5th ed.).* Champaign, IL: Human Kinetics.

Vater, C., Jackson, R.C., Roca, A. and Williams, A.M. (2016) The effects of anxiety on anticipation and visual search in dynamic, time-constrained situations. *Sport, Exercise, and Performance Psychology, 5,* 179-192.

Vickers, J. N. (1996). Visual control when aiming at a far target. *Journal of Experimental Psychology, 22*, 342-354.

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

Williams, A. M., Ford, P. R., Eccles, D. W., & Ward, P. (2011). Perceptual-cognitive expertise in sport and its acquisition: Implications for applied cognitive psychology. *Applied Cognitive Psychology*, *25*, 432-442.

Williams, A. M., Vickers, J. N., Rodrigues, S., & Hillis, F. (2002) Anxiety and performance in table tennis: a test of Eysenck and Calvo's processing efficiency theory. *Journal of Sport and Exercise Psychology, 24,* 438-455.

Williams, A. M., Ward, P., Knowles, J. M., & Smeeton N. J. (2002). Anticipation skill in a real-world task: measurement, training, and transfer in tennis. *Journal Experimental Psychology: Applied, 8,* 259-270.

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

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

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

Zijlstra, F. R. H. (1993). Efficiency in work behaviour: *A design approach for modern tools. Delft*, the Netherlands: Delft University Press.