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Article

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The effects of high- and low-anxiety training on the anticipation judgements of elite performers

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Abstract

We examined the effects of high- versus low-anxiety conditions during video-based training of anticipation judgements by international-level badminton players facing serves and the transfer to high-anxiety and field-based conditions. Players were assigned to a high-anxiety training (HA), low-anxiety training (LA) or control group (CON) in a pre-training-post-test design. In the pre- and post-test, players anticipated serves either from video under high- and low anxiety conditions or live on-court. In the video-based high-anxiety pre-test, anticipation response accuracy was lower and final fixations shorter when compared to the low-anxiety pre-test. In the low-anxiety post-test, HA and LA demonstrated greater accuracy of judgements and longer final fixations compared to pre-test and CON. In the high-anxiety post-test, HA maintained accuracy when compared to the low-anxiety post-test, whereas LA had lower accuracy. In the on-court post-test, the training groups demonstrated greater accuracy of judgements compared to the pre-test and CON.

Key Words: Expert performance, Perceptual-cognitive skill, Pressure training.

The effects of high- and low-anxiety training on the anticipation judgements of elite performers

Skilled athletes are superior at anticipating opponent actions when compared to lesser-skilled athletes (Broadbent, Causer, Williams, & Ford, 2015). To do so, they use vision to scan the performance environment in order to recognize advanced cues emanating from the movements of other athletes (Abernethy, Zawi & Jackson, 2008; Alder, Ford, Causer & Williams, 2014; Ryu, Kim, Abernethy & Mann, 2013; Williams, Ward, Knowles & Smeeton, 2002; Williams & Elliott, 1999). For example, skilled badminton players who are better at anticipating serve locations fixate the racket and wrist more frequently and for longer durations when compared to lesser-skilled players who fixate on the head of the server more often (Alder et al., 2014). Researchers have shown that anticipation judgements are negatively affected by high-anxiety conditions (e.g., Williams & Elliott, 1999). However the ability to anticipate opponent actions can be developed through video-based training interventions (for a review, see Broadbent et al., 2015), but no researchers have examined whether training under high-anxiety conditions would lead to performance being maintained in later high-anxiety situations. The aim of this study was to examine the retention and transfer of anticipation judgements and visual search behaviours from video-based training under high-and low-anxiety conditions to later high-anxiety and field-based conditions.

Researchers have shown that high-anxiety conditions negatively affect sports performance, including anticipation judgements and their underlying visual search behaviours, regardless of skill level (e.g., Williams & Elliott, 1999). The effect of high anxiety on performance and its underlying mechanisms is detailed in *Attentional Control Theory* (ACT; Eysenck, Derakshan, Santos & Calvo, 2007). ACT distinguishes between performance outcome and processing efficiency (i.e., performance outcome divided by the processing resources invested in the task). Processing efficiency can be measured through changes in the underlying processes used during performance, such as mental effort (e.g., Wilson et al., 2007) or visual search behaviours (e.g., Wilson, Wood & Vine, 2009). The theory predicts that under high-anxiety conditions processing efficiency decreases, while performance outcome can be maintained. When processing efficiency continues to decrease, such as when too many resources are allocated to identifying and negating the sources of threat, a decrement in performance outcome occurs (Eysenck et al., 2007; Williams et al., 2002). For example, intermediate-level golf players maintained putting performance outcome under high- compared to low-anxiety conditions. However, they exhibited greater mental effort and a decrease in final fixation duration, demonstrating a reduction in processing efficiency, in high compared to low-anxiety conditions (Wilson et al., 2007; see also, Darke, 1988; Derakshan & Eysenck, 1998; Mann, Williams, Ward & Janelle, 2007). Findings demonstrate that under high-anxiety conditions processing efficiency decreases in an attempt to maintain performance outcome, when compared to low-anxiety conditions.

One method to reduce the negative effects of high-anxiety on performance is to have athletes practice or train while experiencing these conditions (Oudejans & Pijpers. 2010). The goal of training under high-anxiety conditions is to allow athletes to gain experience of, and create strategies for, limiting the adverse effects of high-anxiety on performance. However, there is limited research examining the effects of training interventions undertaken when participants are experiencing high-anxiety. Oudejans and Pijpers (2009, Experiment 2) examined two groups of skilled darts players that practiced throwing under either high- or low-anxiety conditions in a traditional pre-training-post-test design. In the high-anxiety pre-test, the dart throwing performance of both groups was lower when compared to the low-anxiety pre-test. In the low-anxiety post-test, there were no between-group differences in dart throwing performance, but it had improved from the pre-test. In the high-anxiety post-test, the dart throwing performance of the high-anxiety training group did not differ compared to their low-anxiety post-test, whereas performance was significantly lower for the low-anxiety training group. In addition, Oudejans and Pijpers (2010) showed that novice dart players trained under high-anxiety conditions maintained throwing performance in a high- compared to low-anxiety post-test, whereas those trained under low-anxiety conditions performed worse in the high- compared to low-anxiety post-test. The repeated exposure of the high-anxiety training groups to those conditions during training in these studies enabled them to maintain performance outcome between high- and low-anxiety conditions (Oudejans & Pijpers, 2009; 2010).

Few researchers have measured the effect of training under high-anxiety conditions on the underlying mechanisms of performance. Nieuwenhuys and Oudejans (2011) showed that experienced police officers trained to shoot at a target under high-anxiety conditions improved shooting accuracy in a high-anxiety post-test when compared to a low-anxiety training group. In addition, the officers who trained under high-anxiety demonstrated longer final fixations to the target in the post-test when compared to officers trained under low-anxiety. In this study, mental effort scores did not differ between groups, but were greater across the high- compared to low-anxiety conditions. Similarly, Oudejans and Pijpers (2009; 2010) report that, following training, darts players had greater mental effort scores in the high- compared to low-anxiety post-test and that the training intervention had no effect on this underlying mechanism. These findings support the prediction in ACT that processing efficiency decreases in an attempt to maintain performance outcome. However, these studies show that training under high-anxiety conditions does not influence mental effort scores in later high-anxiety conditions when compared to low-anxiety conditions and groups, whereas visual search behaviours appear to be amenable to this type of training.

The researchers (Oudejans & Pijpers, 2009; Oudejans & Pijpers, 2010; Nieuwenhuys & Oudejans, 2011) that have examined the effects of high- and low-anxiety training have used aiming tasks where accuracy of shot on a target is the main dependent variable. Aiming tasks are a closed motor-skill performed in a relatively stable environment where the performer can execute the action at will. In contrast, open skills are performed in a changing environment and require more cognitive involvement in terms of anticipation and decision making judgements to select the appropriate action to perform at the correct time (Wulf, 2007). Nieuwenhuys, Savelsbergh and Oudejans (2015) were the first authors to examine the effect of high- and low-anxiety training on decision making in an open task. They had experienced police officers face video of a suspect with a firearm who shot or did not shoot under high- or low-threat training conditions. The officers were required to decide whether to shot or not. In the high-anxiety pre-test, the decision making judgement accuracy of the officers was lower when compared to the low-anxiety pre-test, supporting previous work showing that anxiety reduces the accuracy of decision making judgements (e.g., Wilson et al., 2009). Despite two groups of officers training under high-anxiety conditions, the decision making accuracy of the training groups decreased in the high-anxiety post-test when compared to the low-anxiety post-test, contradicting previous work with aiming tasks (e.g., Oudejans & Pijpers, 2009). It may be that training under high-anxiety conditions has less effect on tasks that involve cognitive judgements of the type made by the police officers (Nieuwenhuys et al., 2015) when compared to simpler aiming tasks (e.g., Oudejans & Pijpers, 2009; Oudejans & Pijpers, 2010).

Other researchers have shown that anticipation judgements in open sports can be developed through video-based training interventions (for a review, see Broadbent et al., 2014). A key consideration when designing video-based training activities should be to ensure any improvements in anticipation transfer to the field and real-world competition (Broadbent et al., 2015), including situations involving high-anxiety. For example, Smeeton et al. (2005) had intermediate level tennis players view life-sized video clips of tennis shots filmed from the first person perspective. The clips were occluded at ball-racket contact and the players were required to anticipate shot direction. Training groups received different instructional interventions that promoted either explicit or discovery learning. Anticipation judgement performance improved from pre- to post-test for the training groups, whereas a control group did not improve. Moreover, in a field-based transfer test, the training groups produced significantly faster response times compared to the pre-test, whereas the control group did not. In addition, the training group that received explicit instruction demonstrated worse anticipation performance in a high-anxiety post-test compared to the discovery training groups. These data demonstrate the potential of video-based training interventions for developing anticipation decisions that transfer to the field, but show that high-anxiety conditions can be detrimental to anticipation performance. However, researchers (Nieuwenhuys et al., 2015) have failed to show an effect of training under high-anxiety conditions for judgement tasks or on mental effort scores. Therefore, it is unclear whether training under high- compared to low-anxiety conditions would lead to training effects being maintained in later high-anxiety situations for anticipation judgements. Moreover, researchers are yet to investigate the effect of this training on visual search behaviours for judgement tasks.

We examine the effect of video-based training under high- and low-anxiety conditions on anticipation and visual search behaviour in later high-anxiety conditions, as well as assessing the transfer of learning from this training to the real-world version of the sport. A pre-training-post-test design was utilised in which international-level badminton players anticipated serves. The pre- and post-tests contained both video- and field-based tests, with the video-based tests being divided into high- and low-anxiety conditions. The purpose of the video-based tests was to establish the effect of high- versus low-anxiety training. In contrast, the purpose of the field-based tests was to examine the transfer of learning from video-based training to the real-world version of the task, so no anxiety manipulations were included. One group (high-anxiety training group) completed the training under high-anxiety conditions, whereas the other training group completed it under low-anxiety conditions (low-anxiety training group). A third control group did not participate in any training. During training, the two training groups underwent various instructional interventions based on previous research, such as receiving details on the "gold standard" visual search behaviour for anticipating the action (Ryu et al., 2013) and information regarding discriminating kinematics (Savelsbergh, van Gastel & van Kampen, 2010).

We hypothesised no between-group differences in anticipation judgement accuracy in the pre-tests. Response accuracy was expected to be greater for the two training groups in the post- compared to pre-tests and when compared to the control group. In the high-anxiety pre-test, it was expected that there would be lower response accuracy for all groups when compared to the low-anxiety pre-test. In the high-anxiety post-test, the high-anxiety training group were expected to maintain response accuracy when compared to their low-anxiety post-test. In contrast, response accuracy for the low-anxiety training group and control group were expected to be lower in the high- compared to their low-anxiety post-tests (Oudejans & Pijpers, 2009). Processing efficiency was expected to be worse in high- compared to low-anxiety conditions across the experiment, as evidenced through greater mental effort, increased fixation frequency and decreased final fixation duration (Eysenck et al., 2007). However, the high-anxiety training group were expected to demonstrate differences in visual search behaviours, such as longer final fixation duration, in the high-anxiety post-test when compared to the LA and CON groups and the high-anxiety pre-test. In the field-based pre-test, no between-group differences were expected, whereas in the field-based post-test, both training groups were expected to have greater accuracy of anticipation judgements when compared to their pre-test and the control group.

Method

Participants

International-level badminton players (n = 30, M = 21.2 years of age, SD = 2.4) participated. They 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 data collection and all had played regional standard and above for a minimum of five years. Participants were randomly assigned to one of three groups: high-anxiety training (HA; n = 10, female = 3, male = 7), low-anxiety training, (LA; n = 10, female = 2, male = 8) or a control group (CON; n = 10, female = 6, male = 4). Separate one-way ANOVAs showed there were no differences between groups for age, F (2, 29) = 0.39, p = .68, or playing experience, F (2, 29) = 0.02, p = .98. Participants provided informed consent and the local ethics committee provided full approval.

Experimental design

The experiment consisted of three pre-test sessions (two video-based temporal occlusion tests and a field-based test), three video-based training sessions, and three post-test sessions (two video-based temporal occlusion tests and a field-based test). The video-based temporal occlusion tests in each of the pre- and post-test contained either high- or low-anxiety conditions. The HA and LA groups took part in all sessions including the training sessions, whereas the CON group only took part in the pre- and post-tests. Therefore, there were 3 Groups (HA, LA, CON), 2 Tests (pre, post) for both field and video, 3 Training Sessions, and for the video-based tests there were 2 Anxiety Conditions (High, Low).

Tasks

Video-based task. The video-based task was the same video-based temporal occlusion test as used in Alder et al. (2014). During the task, the badminton players were required to anticipate serves from video of a doubles match filmed from the first person perspective that were shown as a series of clips on a large screen and occluded around shuttle/racket contact.

The video-based task took place on a full-sized badminton court. 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 the court at 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 do in a normal badminton match. The two start locations were clearly marked on the floor with an “X” using tape. Participants were required to respond by physically carrying out a shadow shot and to provide verbal confirmation as to the end location of the serve from the six possible locations (short tee, short centre, short wide, long centre, long tee and long wide; see Alder et al., 2014). The shadow return shot was not recorded as a dependent variable, but was used to increase the fidelity of the experiment. A time limit of 3,000 ms post-occlusion was set for the verbal and movement response. Response accuracy (RA) was recorded on each trial. A trial was deemed correct if the verbal response matched the location the shuttle had landed on their side of the court.

Field-based task. The field-based task took place on the same court as the video-based test. It consisted of participants physically responding to live serves from an international level player serving diagonally from the right service box. The serves were completed in a predetermined random order to the same six locations of the court as the video-based task (n = 3 serves to each location). Participants were instructed to move quickly and accurately and to return the shuttle as they would do in match. The same server was used throughout and he was instructed to serve as consistently as possible. A high definition (HD) video camera (Canon XHA1S; Tokyo, Japan) was positioned two metres behind the court to capture participant responses. Any serves that were deemed not legal (e.g., hit the net) were replayed at the end of the sequence so as to limit pre-trial information. RA was recorded on each trial of the field-based sessions. A trial was deemed correct if the first significant lateral, forward or backward, or vertical motion of the racket, hips, shoulder or feet corresponded with the shuttle end location, as per Triolet et al. (2013).

Procedures

Figure 1 shows the timeline for the procedures.

Pre- and post-tests. The video-based pre-test session was split into high- and low-anxiety conditions. In the low-anxiety pre-test (*n* = 36 trials), participants were read a "neutral" statement informing them that their performance was being recorded purely for research purposes, that there would be no consequences for poor performance, and that they would not to be compared to their peers. In the high-anxiety pre-test (*n* = 36 trials), participants were read an anxiety-inducing statement informing them that performance was being filmed, analysed and feedback provided to their coach (Wilson et al., 2007; 2009). Participants were instructed that their performance was to be ranked against their peers. After 10 trials, regardless of performance, all participants were informed their performance was unsatisfactory and they were to start the test again. The two anxiety conditions were counterbalanced across participants. The procedure for the video-based post-tests was identical to the video-based pre-tests, except that a different random order of trials was used. In addition, the participants completed 18 trials of the field-based task as both a pre- and post-test.

Participants completed the Mental Readiness Form version 3 (MRF-3; Krane, 1994) immediately after the last trial in each anxiety condition. The MRF-3 is a tool used for measuring state anxiety. It contains 3 bipolar 7-point Likert scales that consist of *worried* and *not worried*, *tense* and *not tense* and *confident* and *not confident.* For each scale, participants were required to make a mark on the line that corresponds to their level of anxiety at that specific time. On completion of the last trial in each anxiety condition, participants completed the Rating Scale of Mental Effort (RSME; Zijlstra, 1993). The RSME scale rates the mental effort required to complete a task. It ranges from 0 to 150 with a higher score representing greater mental effort. Participants were required to mark a specific point on the scale that corresponds with the mental effort they invested in the task.

Visual search behaviours were recorded in all pre- and post-tests using a mobile eye-tracking system (Applied Science Laboratories, MobileEye XG, Bedford, USA). The mobile eye-tracking system is a head-mounted, monocular system that computes point of gaze within a scene through calculation of the vector between the pupil and cornea. The system was calibrated using a still image taken from one of the trials. Eye movement data were recorded at 25 frames per second and analysed frame-by-frame using video editing software (Adobe Premier Pro Video Editing Software, Version CS 5, San Jose, USA). Two gaze measures were calculated per trial: number of fixations and fixation duration (Abernethy & Russell, 1987; Alder et al., 2014)[i]. A fixation was defined as when participant gaze remained within three degrees of visual angle of a location or moving object for a minimum duration of 120 ms (Vickers, 1996).

Training phase. The training phase consisted of three sessions, each of circa 30 min duration. In each session, training groups completed a video-based temporal occlusion test involving 24 trials, beginning with a block of 12 trials. On each of those 12 trials, following their response, they were provided with immediate feedback as to the outcome of each clip by viewing it in full. The full clip showed the actual landing position of the shuttle, followed by a black screen for 2,000 ms containing white text stating the end location of the shuttle. Subsequently, participants engaged in an instructional intervention in each training session. Following the intervention, participants engaged in another video-based temporal occlusion test of 12 trials that were different to the earlier test, but that contained the same feedback process.

The instructional interventions were based on previous research showing that anticipation judgements and visual search behaviours can be improved through such methods (Abernethy, Schorer, Jackson & Hagemann, 2012; Jackson, Warren & Abernethy, 2006; Ryu et al., 2013; Savelsbergh et al., 2010; Smeeton et al., 2005). In the first training session, the intervention involved participants viewing six videos containing serves that had been manipulated to highlight the two phases of the movement (preparation and execution phase) (Alder et al., 2014). The video was slowed by 80% using video-editing software (Adobe Premier Pro Video Editing Software, Version CS 5, San Jose, USA). At the end of the preparation phase, the video paused for 1500 ms before the execution phase played. In the final frame prior to shuttle contact, the video paused for 1500 ms. During the video, the researcher read a statement that described the two phases of the movement. The statement included when and where the kinematic differences occurred between serves, based upon the kinematic data reported in Alder et al. (2014; see also Ryu et al., 2013).

In the instructional intervention during the second training session, participants viewed a two-minute video that contained footage of the visual search behaviour of an Olympic level player completing the same temporal occlusion test. During the video, the researcher read a statement that described the visual search behaviours adopted by the Olympian. He exhibited behaviours consisting of few fixations of a longer duration upon areas where between-shot kinematic differences were located (Alder et al., 2014). Subsequently, participants were shown five trials of their own visual search from the pre-test. In the instructional intervention during the final training session, the researcher read a statement providing information about how to differentiate serve-types. The information was taken from a coaching manual

(Badminton World Federation, 2013), stating that the backswing determined depth, whereas wrist angle determined direction.

Anxiety levels were manipulated in a different manner between the two groups during each of the training sessions. At the start of each training session, an anxiety-inducing statement was read to the HA group that stated their response accuracy score from the last session was in the bottom 20% of participants within their group and that was the reason for the training. In contrast, the LA group was informed that the training was purely for research purposes. After the first block of 12 trials in each intervention, the HA group were read another anxiety-inducing statement stating that they remained in the bottom 20% for response accuracy in their group. During training, the coach attempted to induce greater anxiety by intermittently informing the HA group that their performance was not at the required level and that they needed to improve. Both training groups completed the MRF-3 in each intervention after the first 12 trials of the temporal occlusion test, but for the HA group this occurred after the anxiety-inducing statement that directly followed the first 12 trials.

Statistical analysis

For the training phase, RA, cognitive anxiety and mental effort were analysed separately using 2 Group (HA, LA) x 3 Training sessions (Training 1, Training 2, Training 3) ANOVAs, where the first factor was between-participants and the second factor a repeated measure. RA and mental effort in the video-based pre- and post-tests were analysed in separate 3 Group (HA, LA, CON) x 2 Test Sessions (Pre, Post) x 2 Anxiety Condition (Low, High) ANOVAs, with repeated measures on the last two factors. ACT predictions focus on cognitive anxiety, so data from the MRF-3 ‘worried’ subscale that measures cognitive anxiety was analysed in a 3 Group (HA, LA, CON) x 2 Test sessions (Pre, Post) x 2 Anxiety condition (High, Low) ANOVA, with repeated measures on the last two factors. RA and mental effort in the field-based sessions were analysed in separate 3 Group (HA, LA, CON) x 2 Test sessions (Pre, Post) ANOVA, with repeated measures on the last factor.

The number of fixations employed in the field-based tests were analysed using a 3 Group (HA, LA, CON) x 2 Test Sessions (Pre, Post) ANOVA, with repeated measures on the last factor, whereas number of fixations in the video-based tests were analysed using the same type of ANOVA with 2 Anxiety Condition (High, Low) as an additional repeated measure. Alder et al. (2014) examined the ability of expert and novice badminton players to anticipate the same serve task as used in the current experiment. Participants in their experiment made two fixations on average during the task and initial inspection of our data revealed a similar mean value. In Alder et al. (2014) differences between groups in visual search duration were found for the final fixation, but not for the preceding fixation. Therefore, in the current experiment, fixation duration was analysed for the final fixation only. Final fixation duration in the video-based tests was analysed using a 3 Group (HA, LA, CON) x 2 Test sessions (Pre, Post) x 2 Anxiety Condition (Low, High) ANOVA, with repeated measures on the last two factors. Final fixation duration in the field-based tests were analysed using a 3 Group (HA, LA, CON) x 2 Test Sessions (Pre, Post) ANOVA, with repeated measures on the last factor.

Any significant interactions were analysed using Tukey's Honestly Significant Difference. Bonferroni comparisons were used for main effects involving more than two variables. Partial eta-squared was used to report effect size. Intra-reliability observer checks were conducted on the visual search data using the test-retest method, with the data from a HA participant (93% reliability), LA participant (95% reliability) and a CON participant (98% reliability) being re-analysed and found to be objective. For all statistical tests, the alpha level for significance was .05.

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Results

Training phase

Anxiety and mental effort. Table 1 shows cognitive anxiety and mental effort scores during the training phase. There were significant main effects of Group for both cognitive anxiety, F (1, 18) = 25.69, p < .01, η_p^2 = .59, and mental effort, F (2, 36) = 19.29, p = .03, η_p^2 = .52. As expected, the HA group reported greater cognitive anxiety and mental effort during the training intervention when compared to the LA. There was no Training Session main effect for cognitive anxiety, F (2, 36) = 1.32 p = .91, η_p^2 = .04, or mental effort, F (2, 36) = 1.93 p = .71, η_p^2 = .08. There was no Group x Training Session interaction for cognitive anxiety, F (2, 36) = 1.45, p = .25, η_p^2 = .08, or mental effort, F (2, 36) = 0.12, p = .81, η_p^2 < .01

Response accuracy. There were no significant Group, F (1, 18) = 3.54, p = .67, η_p^2 = .06, or Testing Session main effects, F (2, 36) = 7.53, p = .37, η_p^2 = .07. There was a significant Group x Training Session interaction, F (2, 36) = 4.59, p = .02, η_p^2 = .21. *Post hoc* tests showed that in the first session there were no between-group differences (p = .32). In the second training session, the LA group improved the accuracy of anticipation judgement compared to the first training session (p = .03), whereas the HA group did not (p = .12). In the third training session, there were no between-group differences (p = .28), but both HA and LA groups had increased the accuracy of anticipation judgement compared to the first (HA p = .03; LA p = .04) and second training session (HA p = .04; LA p = .02).

Pre- and post-test

Anxiety and mental effort. Table 2 shows cognitive anxiety and mental effort in the pre- and post-test. There were significant main effects for Anxiety Condition for both cognitive anxiety, F (1, 27) = 62.41, p < .01, η_p^2 = .69, and mental effort, F (1, 27) = 13.32, p < .01, η_p^2 = .33. As predicted, there was greater cognitive anxiety and mental effort in high-compared to low-anxiety conditions. For cognitive anxiety, there was no Group, F (2, 27) = 2.48, p = .11, η_p^2 = .16, or Testing Session, F (1, 27) = 7.55, p = .09, η_p^2 = .22, main effects. The interactions were not significant between Group x Testing Session, F (2, 27) = 0.42, p = .66, η_p^2 = .03, Anxiety Condition x Group, F (2, 27) = 0.27, p = .77, η_p^2 = .02, Testing Session x Anxiety Condition, F (1, 27) = 0.98, p = .33, η_p^2 = .04, or Testing session x Anxiety condition x Group, F (2, 27) = 0.91, p = .42, η_p^2 = .06. For mental effort, there were no main effects for Group, F (2, 27) = 2.19, p = .13, η_p^2 = .14, or Testing Session, F (1, 27) = 4.21, p = .06, η_p^2 = .36. The interactions were not significant between Group x Testing Session, F (2, 27) = 2.23, p = .13, η_p^2 = .14, Anxiety Condition x Group, F (2, 27) = 0.07, p = .93, η_p^2 < 0.01, Testing Session x Anxiety Condition, F (1, 27) = 1.13, p = .16, η_p^2 = .12, and Testing session x Anxiety condition x Group, F (2, 27) = 1.57, p = .22, η_p^2 = .12.

Response accuracy. Figure 2 shows RA in the video-based sessions as a function of Group, Test Session and Anxiety Condition. There were significant main effects for Group, F (2, 27) = 3.59, p = .04, η_p^2 = 0.21, Test session, F (1, 27) = 43.38, p < .01, η_p^2 = 0.62, and Anxiety Condition, F (1, 27) = 21.34, p < .01, η_p^2 = 0.44. As expected, RA was greater for HA and LA compared to CON, in the post- compared to pre-test, and in the low- compared to high-anxiety conditions. There were two-way interactions for Group x Testing session, F (2, 27) = 11.29, p < .01, η_p^2 = 0.45, Anxiety condition x Group, F (2, 27) = 3.75, p = .04, η_p^2 = 0.22, and Testing session x Anxiety condition, F (1, 27) = 6.33, p = .02, η_p^2 = 0.19. There was a significant three-way Group x Test Session x Anxiety Condition interaction that explained the data, F (2, 27) = 3.71, p = .04, η_p^2 = 0.22. *Post hoc* tests showed that in the low-anxiety pre-test there were no differences in RA between groups (*p's* > .5). In the high-anxiety pre-test, the RA of each group was lower compared to their low anxiety pre-test (*p's* < .02).

In the low anxiety post-test, the LA group and the HA group had significantly greater RA than both their pre-test scores (LA p = .03; HA p = .04) and the CON group (LA p = .01; HA p = .02), whereas there was no difference in RA between the LA and HA group (p = .38). However, in the high-anxiety post-test, as predicted, the HA group had significantly greater RA compared to the LA (p = .04) and the CON (p = .02) groups.

Figure 3 shows RA in the field-based sessions. There were significant main effects for Group, F (2, 27) = 6.15, p = .01, η_p^2 = 0.31, and Test Session, F (1, 27) = 143.61, p < .01, η_p^2 = 0.84. RA was greater for HA and LA compared to CON and in the post- compared to pre-test. There was a significant Group x Test Session interaction, F (1, 27) = 5.74, p < .01, η_p^2 = 0.29. *Post hoc* tests revealed that in the pre-test there was no between-group difference in RA (*p's* > .3). However, in the post-test, both the LA group (p = .04) and HA group (p = .03) had greater RA compared to their pre-test, whereas the CON group did not (p = .32).

Visual search behaviour. Table 3 shows the number of fixations and duration of final visual fixation in the video-based test, whereas Table 4 shows the number of fixations and duration of final fixation (ms) in the field-based test. For number of fixations, there were no main effects for Group, F (2, 27) = 0.34, p = .21, η_p^2 = .03, Test Session, F (1, 27) = 5.39, p = .15, η_p^2 = .36, or Anxiety Condition, F (1, 27) = 3.13, p = .08, η_p^2 = .11, albeit the latter approached significance with fewer fixations under low- compared to high-anxiety conditions. There were no two-way interactions between Group x Testing Session, F (2, 27) = 3.26, p = .09, η_p^2 = .19, Anxiety Condition x Group, F (2, 27) = 3.35, p = .11, η_p^2 = .19, and Testing Session x Anxiety Condition, F (1, 27) = 7.45, p = .09, η_p^2 = .22. However, each of these two-way interactions approached significance because: (i) HA used less fixations in the post- compared to pre-test (p = .09), whereas there were no differences between tests for LA (p = .32) and CON (p = .21); (ii) LA (p = .08) and CON (p = .13) used more fixations in the high- compared to low-anxiety conditions, whereas HA demonstrated no difference between anxiety conditions (p = .43); and (iii) more fixations occurred in the high-anxiety pre-test compared to the low-anxiety post-test (p = .07), but there was no difference between anxiety-conditions elsewhere (p = .32). The Group x Testing session x Anxiety condition interaction was not significant, F (2, 27) = 0.89, p = .42, η_p^2 = .06.

For final fixation duration in the video-based sessions, there was no main effect for Group, F (2, 27) = 2.59, p = .09, η_p^2 = .16, although this approached significance because final fixation duration for CON was shorter compared to LA (p = .12) and HA (p = .09) groups, whereas there was no difference between HA and LA groups (p = .42). There was a main effect for Test, F (1, 27) = 5.52, p = .03, η_p^2 = .17, where final fixation duration was longer in the post- compared to pre-test. There was a main effect for Anxiety Condition, F (1, 27) = 19.19, p < .01, η_p^2 = .42, showing final fixation duration was shorter in the high- compared to low-anxiety condition. There was no Group x Testing Session interaction, F (2, 27) = 1.69, p = .21, η_p^2 = .11, Anxiety condition x Group, F (2, 27) = 0.39, p = .42, η_p^2 = .07, or Testing session x Anxiety condition, F (1, 27) = 1.89, p = .19, η_p^2 = .02, interactions. The Testing session x Anxiety condition x Group interaction was not significant, but approached significance, F (2, 27) = 1.65, p = .11, η_p^2 = .21. In the high-anxiety post-test, final fixation duration for HA was not different to the low-anxiety post-test (p = .27), whereas it was shorter for LA (p = .09) and CON (p = .12) compared to the low-anxiety post-test, and not different elsewhere.

In the field-based sessions, the number of fixations did not differ as function of Group, F (2, 27) = 0.07, p = .94, η_p^2 < .01, or Test Session, F (1, 27) = 0.60, p = .45, η_p^2 = .02, nor was the Group x Test Session significant, F (2, 27) = 0.13, p = .88, η_p^2 = .01. For duration of final fixation in the field-based sessions, there was no main effects for Group, F (2, 27) = 0.92, p = .34, η_p^2 < .01, or Testing Session, F (1, 27) = 2.87, p = .11, η_p^2 = .09, although the latter approached significance with longer final fixation durations in the post- compared to pre-test. There was no Group x Testing Session interaction, F (2, 27) = 2.49, p = .12, η_p^2 = .16.

Discussion

We examined the training of anticipation judgement and visual search behaviours in international-level badminton players under high- compared to low-anxiety conditions and the extent to which any improvement in performance was retained under high-anxiety conditions and a transfer test a field-based condition. The training intervention led to an increase in the accuracy of anticipation judgements for both LA and HA groups in the post- compared to the pre-tests relative to a control group. Moreover, final fixation duration was significantly longer in the post- compared to pre-test. In the high-anxiety post-test, the accuracy of anticipation judgements for the LA group decreased when compared to the low-anxiety post-test. In contrast, the HA group maintained the accuracy of their anticipation judgements across anxiety conditions in the post-test. In addition, final fixation duration for the HA group was not significantly different between the high- and low-anxiety post-test, whereas for the LA and CON groups there was a trend (p = .11) towards a shorter final fixation duration in the high- compared to low-anxiety post-test. Other measures of professing efficiency (mental effort, number of fixations) did not differentiate groups across tests.

As predicted, in the high-anxiety post-test, the anticipation accuracy of the HA group did not differ from their low-anxiety post-test. However, for the LA and CON groups, lower anticipation accuracy scores were reported in the high- compared with low-anxiety post-test. Given the lack of differences in RA between the three groups in the pre-test, the post-test data supports previous research (e.g., Oudejans & Pijpers, 2009) showing that training under high-anxiety leads to greater retention of performance under subsequent high-anxiety conditions, when compared to low-anxiety training. Findings demonstrate that this effect extends to anticipation judgements in sport. ACT predicts that high-anxiety leads to an increase in effort, thus a decrease in processing efficiency, in an attempt to limit the potentially detrimental effects of anxiety on performance outcome (Eysenck et al., 2007). In support of this prediction, the HA group demonstrated greater mental effort during training compared to the LA group and mental effort was generally greater for both groups under high- compared to low-anxiety conditions. Findings supports ACT and previous research (e.g., Wilson et al., 2007) showing that high-anxiety results in a reduction in performance efficiency as evidenced by increased effort in an attempt to maintain performance outcome (Murray & Janelle, 2003; Wilson et al., 2009).

As expected, the HA group maintained performance outcome between the high- and low-anxiety conditions in the post-test and this was underpinned by a lack of difference in visual search behaviours between anxiety conditions. The high-anxiety training resulted in the HA group being able to maintain final fixation durations in the high-anxiety post-test when compared to the low-anxiety post-test. In contrast, data suggests that in the high-anxiety post-test the LA and CON groups demonstrated final fixation durations which were shorter compared to the low-anxiety post-test along with a reduction in performance outcome, when compared to the low-anxiety post-test and the HA group, albeit this interaction only approached significance ($p = .11$). These findings support previous research showing that longer final fixations coupled with fewer fixations characterises expert performance in racket sports (e.g., Alder et al., 2014), perhaps by allowing time for maximal information processing to occur (Mann et al., 2007) and limiting the opportunity for distracting stimuli to interrupt performance (Wilson et al., 2007). It extends previous research (e.g., Oudejans & Pijpers, 2009) by showing that training should expose individuals to competition-like stressors, allowing them to develop more effective visual search behaviours to counter the negative effects of high-anxiety and improve performance in those conditions.

It was expected that performance improvements established in the video-based training would transfer to a field-based condition. Our data support this hypothesis with both training groups reporting higher accuracy scores in the field-based post-test when compared to the pre-test and CON group. Findings support previous research (e.g., Farrow & Abernethy, 2002; Ryu et al., 2013; Williams et al., 2002) showing that training interventions involving representative tasks that simulate the performance environment are an effective method for developing anticipation judgement that transfers to the field. During the training phase, the training groups were likely able to refine their task-specific skills and knowledge allowing them to improve the processing of information, which led to a greater transfer of the developed behaviours from the video- to field-based sessions. Moreover, as expected, the training phase led to a general increase in the accuracy of anticipation judgements on the video-based post-test. The training groups demonstrated more accurate anticipation judgements in the low-anxiety post-test compared to the pre-test and CON, whereas the CON did not improve. These findings support previous research showing training interventions highlighting the most effective visual search behaviour are an effective method for developing anticipation judgement (Abernethy et al., 2012; Ryu et al., 2013; Smeeton et al., 2005). The majority of research in this area has focused upon developing anticipation judgement in novice (Abernethy et al., 2007) or intermediate level athletes (Smeeton et al., 2005; for exceptions see Causer et al., 2011). Our data extends this work by showing that international-level athletes can benefit from simulation training and it can lead to significant improvements in anticipation judgments.

In accordance with ACT, processing efficiency was expected to generally reduce under high-compared to low-anxiety conditions (Eysenck et al., 2007). In line with these predictions, high-anxiety conditions generally lead to greater mental effort when compared to the low-anxiety conditions. In addition, under high-anxiety conditions, final fixation duration was generally shorter when compared to low-anxiety conditions. However, data for the number of fixations contradict this prediction, as there was no effect of anxiety. These contradictory findings could possibly be attributed to the constraints of the task. The badminton serve has a short movement duration and short phases within the movement (e.g., execution phase of 1,900 ms duration, see Alder et al., 2014). Therefore, the duration of the task may not have provided sufficient time for the differences in fixation frequency normally found for anxiety and for fixation duration differences to become apparent. Regardless, the HA group was able to maintain longer final fixation durations between the high- and low-anxiety post-tests, whereas the durations became shorter for the LA and CON group in the high- compared to low-anxiety post-test, albeit this interaction only approached significance (p = .11). A potential reason for this three-way interaction for final fixation duration failing to reach significance may be lower statistical power due to the sample size in this study (n = 10 per group). However, the sample size employed was representative of those used in previous research in this area (e.g. Savelsbergh et al., 2002; Smeeton et al., 2005) and the population size of truly expert athletes from which the sample was drawn is relatively small.

A limitation to these type of studies is the indirect method of measuring attention, usually by self-report measures or visual search behaviours. This makes it difficult to ascertain how attention is allocated or the specific strategies individuals use to overcome working memory constraints. For example, one explanation for the between-group difference in anticipation judgements could be related to differences in attentional resource delegation strategies acquired from the different training protocols. That is, through exposure to high-anxiety training, the HA group may have acquired the ability to delegate attentional resources more efficiently and effectively under later high-anxiety conditions. Conversely, the low-anxiety training did not allow the LA group to develop these strategies. However, without a direct measure of attention allocation we can only postulate as to the effect that training has on attentional strategies. Future research is needed to use more direct measures of attention allocation to determine the differences in attention strategies developed by these training protocols. Furthermore, researchers should examine if these attentional changes lead to changes in brain activation and to adaptation of memory structures used by these highly skilled athletes. In summary, a video-based training intervention under high-anxiety conditions led to better retention and transfer of learning to subsequent test conditions involving high-anxiety when compared to low-anxiety training conditions. In contrast, training under low-anxiety conditions led to decrements in anticipation performance and a suggested change in visual search behaviour under high-compared to low-anxiety retention tests. It appears that exposing athletes to high-anxiety during training allows them to modify their behaviours in order to maintain performance in future high-anxiety conditions. In addition, the video-based training intervention improved the accuracy of anticipation judgement, with these positive effects transferring to the field setting.

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Figures

<u>1. Pre-test</u>

Low-anxiety laboratory (*n* = 36 trials)

High-anxiety laboratory (*n* = 36 trials)

Field-based session (*n* = 18 trials)

<u>2. Training phase</u>

Intervention 1	1. Temporal occlusion test and feedback (*n* = 12 trials) 2. Manipulated videos and info on kinematics of movement 3. Temporal occlusion test and feedback (*n* = 12 trials) 4. MRF-3 and RSME
Intervention 2	1. Temporal occlusion test and feedback (*n* = 12 trials) 2. Examples of “gold standard” visual search 3. Temporal occlusion test and feedback (*n* = 12 trials) 4. MRF-3 and RSME
Intervention 3	1. Temporal occlusion test and feedback (*n* = 12 trials) 2. Examples of own visual search from pre-test 3. Temporal occlusion test and feedback (*n* = 12 trials) 4. MRF-3 and RSME

<u>3. Post-test</u>

Low-anxiety laboratory (*n* = 36 trials)

High-anxiety laboratory (*n* = 36 trials)

Field-based session (*n* = 18 trials)

Figure 1: Timeline of experimental process

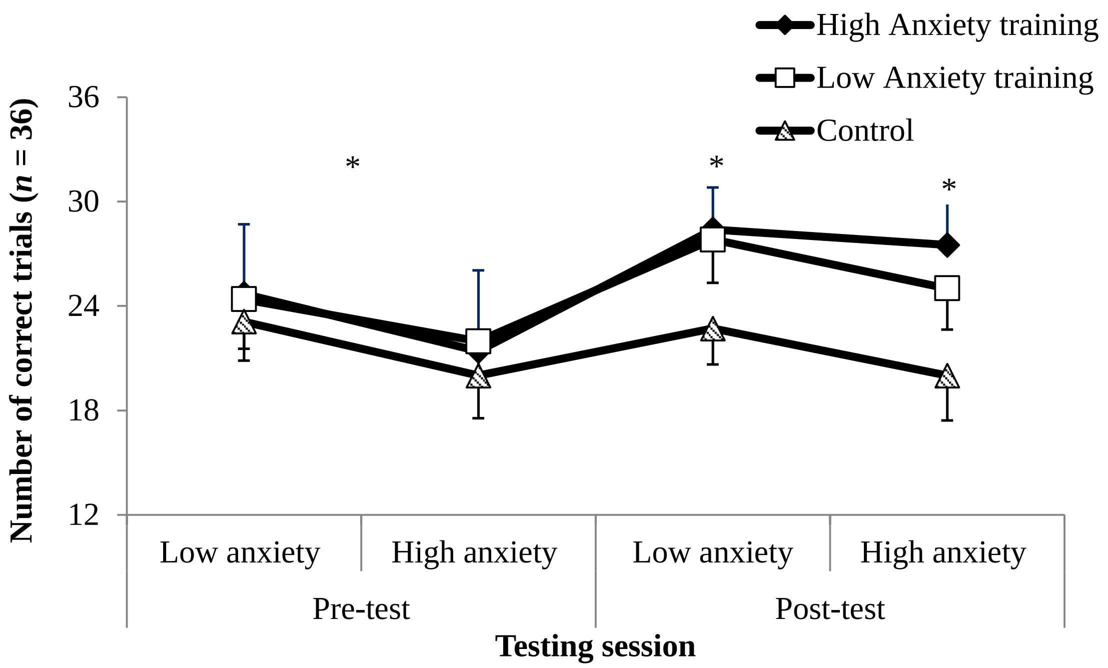

Figure 2. Mean (SD) response accuracy (number of trials) for the three groups on the video-based task across the pre-, training, and post-tests.

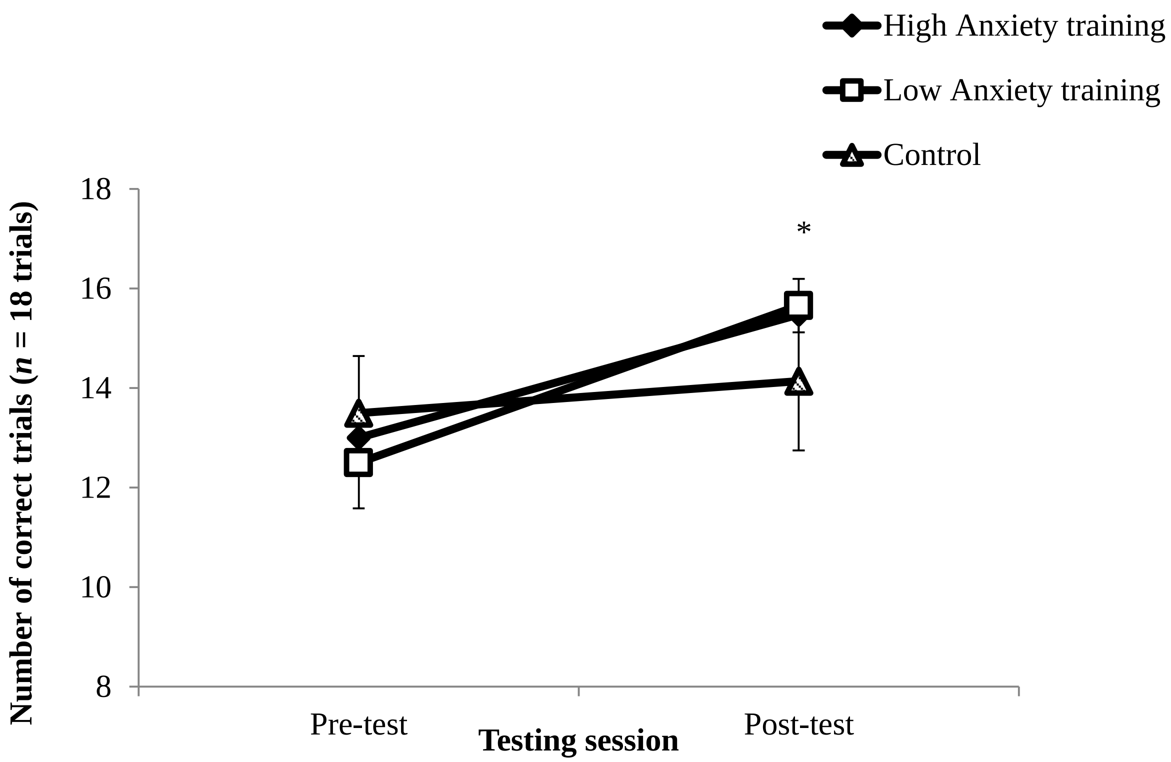

Figure 3. Mean (SD) response accuracy (number of trials) for the three groups on the field-based task in the pre- and post-tests.

Table 1. Mean (SD) scores for cognitive anxiety from the MRF-3 and mental effort from the RSME during the training phase.

	COGNITIVE ANXIETY SUBSCALE OF MRF-3		MENTAL EFFORT FROM RSME	
Training phase	*HA*	*LA*	*HA*	*LA*
Intervention 1	5.12 (2.12)	3.41 (0.91)	86.55 (21.02)	51.89 (22.89)
Intervention 2	6.12 (3.33)	3.30 (3.02)	90.43 (16.43)	58.43 (18.76)
Intervention 3	6.52 (2.24)	4.00 (1.48)	91.02 (22.31)	61.89 (16.98)

Table 2. Mean (SD) scores for the cognitive anxiety subscale of the MRF-3 and for mental effort from the RSME in the video-based test.

	COGNITIVE ANXIETY SUBSCALE OF MRF-3				MENTAL EFFORT FROM RSME			
	Low-anxiety pre-test	High-anxiety pre-test	Low-anxiety post-test	High-anxiety post-test	Low-anxiety pre-test	High-anxiety pre-test	Low-anxiety post-test	High-anxiety post-test
HA	3.61	6.11	4.33	5.81	69.00	86.00	61.43	74.02
	(3.12)	(3.22)	(2.33)	(2.33)	(27.67)	(21.71)	(24.24)	(18.37)
LA	3.00	5.31	3.81	4.12	52.50	71.30	46.50	54.30
	(1.94)	(3.13)	(1.23)	(2.67)	(23.12)	(20.41)	(25.71)	(22.12)
CON	3.25	5.40	4.22	6.13	60.82	72.40	63.60	75.20
	(1.91)	(2.99)	(1.48)	(2.88)	(22.84)	(17.76)	(24.05)	(20.09)

Table 3. Mean (SD) number of fixations and duration of final visual fixation (ms) in the video-based test.

	NUMBER OF FIXATIONS				DURATION OF FINAL FIXATION (ms)			
	Low-anxiety pre-test	High-anxiety pre-test	Low-anxiety post-test	High-anxiety post-test	Low-anxiety pre-test	High-anxiety pre-test	Low-anxiety post-test	High-anxiety post-test
HA	2.4 (0.4)	2.4 (0.3)	2.1 (0.5)	1.9 (0.3)	1880 (358)	1741 (215)	1983 (44)	1851 (104)
LA	1.9 (0.4)	2.5 (0.6)	2.2 (0.5)	2.1 (0.3)	1840 (159)	1822 (183)	2074 (180)	1796 (199)
CON	2.1 (0.2)	2.6 (0.3)	2.2 (0.3)	2.1 (0.3)	1886 (154)	1633 (299)	1890 (110)	1615 (319)

Table 4. Mean (SD) number of fixations and duration of final fixation (ms) in the field-based test.

	NUMBER OF FIXATIONS		DURATION OF FINAL FIXATION (ms)	
	Pre-test	Post-test	Pre-test	Post-test
HA	2.3 (0.5)	2.3 (0.4)	1753 (159)	1914 (63)
LA	2.2 (0.6)	2.3 (0.7)	1831 (217)	1875 (223)
CON	2.1 (0.5)	2.2 (0.5)	1844 (154)	1816 (220)

[i] Location of final fixation was collected and analysed. However, upon inspection of the data, there were no between-group or -test differences in this data set. Therefore the authors did not include this variable in the manuscript so as to reduce the length and complexity of results and in order to maximise reader comprehension.