The Effects of High- and Low-Anxiety Training on the Anticipation Judgments of Elite Performers

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26   **Abstract**

27   We examined the effects of high- versus low-anxiety conditions during video-based

28   training of anticipation judgements by international-level badminton players facing serves and

29   the transfer to high-anxiety and field-based conditions. Players were assigned to a high-anxiety

30   training (HA), low-anxiety training (LA) or control group (CON) in a pre-training-post-test

31   design. In the pre- and post-test, players anticipated serves either from video under high- and

32   low anxiety conditions or live on-court. In the video-based high-anxiety pre-test, anticipation

33   response accuracy was lower and final fixations shorter when compared to the low-anxiety pre-

34   test. In the low-anxiety post-test, HA and LA demonstrated greater accuracy of judgements and

35   longer final fixations compared to pre-test and CON. In the high-anxiety post-test, HA

36   maintained accuracy when compared to the low-anxiety post-test, whereas LA had lower

37   accuracy. In the on-court post-test, the training groups demonstrated greater accuracy of

38   judgements compared to the pre-test and CON.

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

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

49 **performers**

50   Skilled athletes are superior at anticipating opponent actions when compared to lesser-

51 skilled athletes (Broadbent, Causer, Williams, & Ford, 2015). To do so, they use vision to

52 scan the performance environment in order to recognize advanced cues emanating from the

53 movements of other athletes (Abernethy, Zawi & Jackson, 2008; Alder, Ford, Causer &

54 Williams, 2014; Ryu, Kim, Abernethy & Mann, 2013; Williams, Ward, Knowles & Smeeton,

55 2002; Williams & Elliott, 1999). For example, skilled badminton players who are better at

56 anticipating serve locations fixate the racket and wrist more frequently and for longer

57 durations when compared to lesser-skilled players who fixate on the head of the server more

58 often (Alder et al., 2014). Researchers have shown that anticipation judgements are

59 negatively affected by high-anxiety conditions (e.g., Williams & Elliott, 1999). However the

60 ability to anticipate opponent actions can be developed through video-based training

61 interventions (for a review, see Broadbent et al., 2015), but no researchers have examined

62 whether training under high-anxiety conditions would lead to performance being maintained

63 in later high-anxiety situations. The aim of this study was to examine the retention and

64 transfer of anticipation judgements and visual search behaviours from video-based training

65 under high-and low-anxiety conditions to later high-anxiety and field-based conditions.

66   Researchers have shown that high-anxiety conditions negatively affect sports

67 performance, including anticipation judgements and their underlying visual search

68 behaviours, regardless of skill level (e.g., Williams & Elliott, 1999). The effect of high

69 anxiety on performance and its underlying mechanisms is detailed in *Attentional Control*

70 *Theory* (ACT; Eysenck, Derakshan, Santos & Calvo, 2007). ACT distinguishes between

71 performance outcome and processing efficiency (i.e., performance outcome divided by the

72 processing resources invested in the task). Processing efficiency can be measured through

73   changes in the underlying processes used during performance, such as mental effort (e.g.,

74   Wilson et al., 2007) or visual search behaviours (e.g., Wilson, Wood & Vine, 2009). The

75   theory predicts that under high-anxiety conditions processing efficiency decreases, while

76   performance outcome can be maintained. When processing efficiency continues to decrease,

77   such as when too many resources are allocated to identifying and negating the sources of

78   threat, a decrement in performance outcome occurs (Eysenck et al., 2007; Williams et al.,

79   2002). For example, intermediate-level golf players maintained putting performance outcome

80   under high- compared to low-anxiety conditions. However, they exhibited greater mental

81   effort and a decrease in final fixation duration, demonstrating a reduction in processing

82   efficiency, in high compared to low-anxiety conditions (Wilson et al., 2007; see also, Darke,

83   1988; Derakshan & Eysenck, 1998; Mann, Williams, Ward & Janelle, 2007). Findings

84   demonstrate that under high-anxiety conditions processing efficiency decreases in an attempt

85   to maintain performance outcome, when compared to low-anxiety conditions.

86   One method to reduce the negative effects of high-anxiety on performance is to have

87   athletes practice or train while experiencing these conditions (Oudejans & Pijpers. 2010). The

88   goal of training under high-anxiety conditions is to allow athletes to gain experience of, and

89   create strategies for, limiting the adverse effects of high-anxiety on performance. However,

90   there is limited research examining the effects of training interventions undertaken when

91   participants are experiencing high-anxiety. Oudejans and Pijpers (2009, Experiment 2)

92   examined two groups of skilled darts players that practiced throwing under either high- or

93   low-anxiety conditions in a traditional pre-training-post-test design. In the high-anxiety pre-

94   test, the dart throwing performance of both groups was lower when compared to the low-

95   anxiety pre-test. In the low-anxiety post-test, there were no between-group differences in dart

96   throwing performance, but it had improved from the pre-test. In the high-anxiety post-test,

97   the dart throwing performance of the high-anxiety training group did not differ compared to

98   their low-anxiety post-test, whereas performance was significantly lower for the low-anxiety

99   training group. In addition, Oudejans and Pijpers (2010) showed that novice dart players

100 trained under high-anxiety conditions maintained throwing performance in a high- compared

101 to low-anxiety post-test, whereas those trained under low-anxiety conditions performed

102 worse in the high- compared to low-anxiety post-test. The repeated exposure of the high-

103 anxiety training groups to those conditions during training in these studies enabled them to

104 maintain performance outcome between high- and low-anxiety conditions (Oudejans &

105 Pijpers, 2009; 2010).

106   Few researchers have measured the effect of training under high-anxiety conditions on

107 the underlying mechanisms of performance. Nieuwenhuys and Oudejans (2011) showed that

108 experienced police officers trained to shoot at a target under high-anxiety conditions

109 improved shooting accuracy in a high-anxiety post-test when compared to a low-anxiety

110 training group. In addition, the officers who trained under high-anxiety demonstrated longer

111 final fixations to the target in the post-test when compared to officers trained under low-

112 anxiety. In this study, mental effort scores did not differ between groups, but were greater

113 across the high- compared to low-anxiety conditions. Similarly, Oudejans and Pijpers (2009;

114 2010) report that, following training, darts players had greater mental effort scores in the

115 high- compared to low-anxiety post-test and that the training intervention had no effect on

116 this underlying mechanism. These findings support the prediction in ACT that processing

117 efficiency decreases in an attempt to maintain performance outcome. However, these studies

118 show that training under high-anxiety conditions does not influence mental effort scores in

119 later high-anxiety conditions when compared to low-anxiety conditions and groups, whereas

120 visual search behaviours appear to be amenable to this type of training.

121   The researchers (Oudejans & Pijpers, 2009; Oudejans & Pijpers, 2010; Nieuwenhuys &

122 Oudejans, 2011) that have examined the effects of high- and low-anxiety training have used

123   aiming tasks where accuracy of shot on a target is the main dependent variable. Aiming tasks

124   are a closed motor-skill performed in a relatively stable environment where the performer can

125   execute the action at will. In contrast, open skills are performed in a changing environment

126   and require more cognitive involvement in terms of anticipation and decision making

127   judgements to select the appropriate action to perform at the correct time (Wulf, 2007).

128   Nieuwenhuys, Savelsbergh and Oudejans (2015) were the first authors to examine the effect

129   of high- and low-anxiety training on decision making in an open task. They had experienced

130   police officers face video of a suspect with a firearm who shot or did not shoot under high- or

131   low-threat training conditions. The officers were required to decide whether to shot or not. In

132   the high-anxiety pre-test, the decision making judgement accuracy of the officers was lower

133   when compared to the low-anxiety pre-test, supporting previous work showing that anxiety

134   reduces the accuracy of decision making judgements (e.g., Wilson et al., 2009). Despite two

135   groups of officers training under high-anxiety conditions, the decision making accuracy of

136   the training groups decreased in the high-anxiety post-test when compared to the low-anxiety

137   post-test, contradicting previous work with aiming tasks (e.g., Oudejans & Pijpers, 2009). It

138   may be that training under high-anxiety conditions has less effect on tasks that involve

139   cognitive judgements of the type made by the police officers (Nieuwenhuys et al., 2015)

140   when compared to simpler aiming tasks (e.g., Oudejans & Pijpers, 2009; Oudejans & Pijpers,

141   2010).

142   Other researchers have shown that anticipation judgements in open sports can be

143   developed through video-based training interventions (for a review, see Broadbent et al.,

144   2014). A key consideration when designing video-based training activities should be to

145   ensure any improvements in anticipation transfer to the field and real-world competition

146   (Broadbent et al., 2015), including situations involving high-anxiety. For example, Smeeton

147   et al. (2005) had intermediate level tennis players view life-sized video clips of tennis shots

148   filmed from the first person perspective. The clips were occluded at ball-racket contact and

149   the players were required to anticipate shot direction. Training groups received different

150   instructional interventions that promoted either explicit or discovery learning. Anticipation

151   judgement performance improved from pre- to post-test for the training groups, whereas a

152   control group did not improve. Moreover, in a field-based transfer test, the training groups

153   produced significantly faster response times compared to the pre-test, whereas the control

154   group did not. In addition, the training group that received explicit instruction demonstrated

155   worse anticipation performance in a high-anxiety post-test compared to the discovery training

156   groups. These data demonstrate the potential of video-based training interventions for

157   developing anticipation decisions that transfer to the field, but show that high-anxiety

158   conditions can be detrimental to anticipation performance. However, researchers

159   (Nieuwenhuys et al., 2015) have failed to show an effect of training under high-anxiety

160   conditions for judgement tasks or on mental effort scores. Therefore, it is unclear whether

161   training under high- compared to low-anxiety conditions would lead to training effects being

162   maintained in later high-anxiety situations for anticipation judgements. Moreover, researchers

163   are yet to investigate the effect of this training on visual search behaviours for judgement

164   tasks.

165   We examine the effect of video-based training under high- and low-anxiety conditions

166   on anticipation and visual search behaviour in later high-anxiety conditions, as well as

167   assessing the transfer of learning from this training to the real-world version of the sport. A

168   pre-training-post-test design was utilised in which international-level badminton players

169   anticipated serves. The pre- and post-tests contained both video- and field-based tests, with

170   the video-based tests being divided into high- and low-anxiety conditions. The purpose of the

171   video-based tests was to establish the effect of high- versus low-anxiety training. In contrast,

172   the purpose of the field-based tests was to examine the transfer of learning from video-based

173   training to the real-world version of the task, so no anxiety manipulations were included. One

174   group (high-anxiety training group) completed the training under high-anxiety conditions,

175   whereas the other training group completed it under low-anxiety conditions (low-anxiety

176   training group). A third control group did not participate in any training. During training, the

177   two training groups underwent various instructional interventions based on previous research,

178   such as receiving details on the "gold standard" visual search behaviour for anticipating the

179   action (Ryu et al., 2013) and information regarding discriminating kinematics (Savelsbergh,

180   van Gastel & van Kampen, 2010).

181   We hypothesised no between-group differences in anticipation judgement accuracy in

182   the pre-tests. Response accuracy was expected to be greater for the two training groups in the

183   post- compared to pre-tests and when compared to the control group. In the high-anxiety pre-

184   test, it was expected that there would be lower response accuracy for all groups when

185   compared to the low-anxiety pre-test. In the high-anxiety post-test, the high-anxiety training

186   group were expected to maintain response accuracy when compared to their low-anxiety

187   post-test. In contrast, response accuracy for the low-anxiety training group and control group

188   were expected to be lower in the high- compared to their low-anxiety post-tests (Oudejans &

189   Pijpers, 2009). Processing efficiency was expected to be worse in high- compared to low-

190   anxiety conditions across the experiment, as evidenced through greater mental effort,

191   increased fixation frequency and decreased final fixation duration (Eysenck et al., 2007).

192   However, the high-anxiety training group were expected to demonstrate differences in visual

193   search behaviours, such as longer final fixation duration, in the high-anxiety post-test when

194   compared to the LA and CON groups and the high-anxiety pre-test. In the field-based pre-

195   test, no between-group differences were expected, whereas in the field-based post-test, both

196   training groups were expected to have greater accuracy of anticipation judgements when

197   compared to their pre-test and the control group.

Method

199   **Participants**

200   International-level badminton players ($n = 30$, $M = 21.2$ years of age, $SD = 2.4$)

201   participated. They had accumulated an average of 13 years ($SD = 2.4$) experience in

202   competition. They were taking part in at least 20 hours a week of badminton practice at the

203   time of data collection and all had played regional standard and above for a minimum of five

204   years. Participants were randomly assigned to one of three groups: high-anxiety training (HA;

205     $n = 10$, female = 3, male = 7), low-anxiety training, (LA; $n = 10$, female = 2, male = 8) or a

206   control group (CON; $n = 10$, female = 6, male = 4). Separate one-way ANOVAs showed

207   there were no differences between groups for age, $F (2, 29) = 0.39$, $p = .68$, or playing

208   experience, $F (2, 29) = 0.02$, $p = .98$. Participants provided informed consent and the local

209   ethics committee provided full approval.

210   **Experimental design**

211   The experiment consisted of three pre-test sessions (two video-based temporal

212   occlusion tests and a field-based test), three video-based training sessions, and three post-test

213   sessions (two video-based temporal occlusion tests and a field-based test). The video-based

214   temporal occlusion tests in each of the pre- and post-test contained either high- or low-

215   anxiety conditions. The HA and LA groups took part in all sessions including the training

216   sessions, whereas the CON group only took part in the pre- and post-tests. Therefore, there

217   were 3 Groups (HA, LA, CON), 2 Tests (pre, post) for both field and video, 3 Training

218   Sessions, and for the video-based tests there were 2 Anxiety Conditions (High, Low).

219   **Tasks**

220   **Video-based task.** The video-based task was the same video-based temporal occlusion

221   test as used in Alder et al. (2014). During the task, the badminton players were required to

222 anticipate serves from video of a doubles match filmed from the first person perspective that

223 were shown as a series of clips on a large screen and occluded around shuttle/racket contact.

224   The video-based task took place on a full-sized badminton court. The test film was back

225 projected life-size onto a two-dimensional screen (size: 2.74 metres high x 3.66 metres wide;

226 Draper, USA). The screen was positioned on the opposite side of the court at 1.98 metres

227 from where the net would be in a position that provided the most representative view of the

228 serves. Participants were required to start each trial on either the left or right hand side of the

229 service area, as they would do in a normal badminton match. The two start locations were

230 clearly marked on the floor with an "X" using tape. Participants were required to respond by

231 physically carrying out a shadow shot and to provide verbal confirmation as to the end

232 location of the serve from the six possible locations (short tee, short centre, short wide, long

233 centre, long tee and long wide; see Alder et al., 2014). The shadow return shot was not

234 recorded as a dependent variable, but was used to increase the fidelity of the experiment. A

235 time limit of 3,000 ms post-occlusion was set for the verbal and movement response.

236 Response accuracy (RA) was recorded on each trial. A trial was deemed correct if the verbal

237 response matched the location the shuttle had landed on their side of the court.

238   **Field-based task.** The field-based task took place on the same court as the video-

239 based test. It consisted of participants physically responding to live serves from an

240 international level player serving diagonally from the right service box. The serves were

241 completed in a predetermined random order to the same six locations of the court as the

242 video-based task ($n = 3$ serves to each location). Participants were instructed to move quickly

243 and accurately and to return the shuttle as they would do in match. The same server was used

244 throughout and he was instructed to serve as consistently as possible. A high definition (HD)

245 video camera (Canon XHA1S; Tokyo, Japan) was positioned two metres behind the court to

246 capture participant responses. Any serves that were deemed not legal (e.g., hit the net) were

247 replayed at the end of the sequence so as to limit pre-trial information. RA was recorded on

248 each trial of the field-based sessions. A trial was deemed correct if the first significant lateral,

249 forward or backward, or vertical motion of the racket, hips, shoulder or feet corresponded

250 with the shuttle end location, as per Triolet et al. (2013).

251 **Procedures**

252 Figure 1 shows the timeline for the procedures.

253 **Pre- and post-tests.** The video-based pre-test session was split into high- and low-

254 anxiety conditions. In the low-anxiety pre-test ($n = 36$ trials), participants were read a

255 "neutral" statement informing them that their performance was being recorded purely for

256 research purposes, that there would be no consequences for poor performance, and that they

257 would not to be compared to their peers. In the high-anxiety pre-test ($n = 36$ trials),

258 participants were read an anxiety-inducing statement informing them that performance was

259 being filmed, analysed and feedback provided to their coach (Wilson et al., 2007; 2009).

260 Participants were instructed that their performance was to be ranked against their peers. After

261 10 trials, regardless of performance, all participants were informed their performance was

262 unsatisfactory and they were to start the test again. The two anxiety conditions were

263 counterbalanced across participants. The procedure for the video-based post-tests was

264 identical to the video-based pre-tests, except that a different random order of trials was used.

265 In addition, the participants completed 18 trials of the field-based task as both a pre- and

266 post-test.

267 Participants completed the Mental Readiness Form version 3 (MRF-3; Krane, 1994)

268 immediately after the last trial in each anxiety condition. The MRF-3 is a tool used for

269 measuring state anxiety. It contains 3 bipolar 7-point Likert scales that consist of *worried* and

270 *not worried*, *tense* and *not tense* and *confident* and *not confident*. For each scale, participants

271 were required to make a mark on the line that corresponds to their level of anxiety at that

272   specific time. On completion of the last trial in each anxiety condition, participants completed

273   the Rating Scale of Mental Effort (RSME; Zijlstra, 1993). The RSME scale rates the mental

274   effort required to complete a task. It ranges from 0 to 150 with a higher score representing

275   greater mental effort. Participants were required to mark a specific point on the scale that

276   corresponds with the mental effort they invested in the task.

277   Visual search behaviours were recorded in all pre- and post-tests using a mobile eye-

278   tracking system (Applied Science Laboratories, MobileEye XG, Bedford, USA). The mobile

279   eye-tracking system is a head-mounted, monocular system that computes point of gaze within

280   a scene through calculation of the vector between the pupil and cornea. The system was

281   calibrated using a still image taken from one of the trials. Eye movement data were recorded

282   at 25 frames per second and analysed frame-by-frame using video editing software (Adobe

283   Premier Pro Video Editing Software, Version CS 5, San Jose, USA). Two gaze measures

284   were calculated per trial: number of fixations and fixation duration (Abernethy & Russell,

285   1987; Alder et al., 2014)[i]. A fixation was defined as when participant gaze remained within

286   three degrees of visual angle of a location or moving object for a minimum duration of 120

287   ms (Vickers, 1996).

288   **Training phase.** The training phase consisted of three sessions, each of circa 30 min

289   duration. In each session, training groups completed a video-based temporal occlusion test

290   involving 24 trials, beginning with a block of 12 trials. On each of those 12 trials, following

291   their response, they were provided with immediate feedback as to the outcome of each clip by

292   viewing it in full. The full clip showed the actual landing position of the shuttle, followed by

293   a black screen for 2,000 ms containing white text stating the end location of the shuttle.

294   Subsequently, participants engaged in an instructional intervention in each training session.

295   Following the intervention, participants engaged in another video-based temporal occlusion

296   test of 12 trials that were different to the earlier test, but that contained the same feedback

297   process.

298   The instructional interventions were based on previous research showing that

299   anticipation judgements and visual search behaviours can be improved through such methods

300   (Abernethy, Schorer, Jackson & Hagemann, 2012; Jackson, Warren & Abernethy, 2006; Ryu

301   et al., 2013; Savelsbergh et al., 2010; Smeeton et al., 2005). In the first training session, the

302   intervention involved participants viewing six videos containing serves that had been

303   manipulated to highlight the two phases of the movement (preparation and execution phase)

304   (Alder et al., 2014). The video was slowed by 80% using video-editing software (Adobe

305   Premier Pro Video Editing Software, Version CS 5, San Jose, USA). At the end of the

306   preparation phase, the video paused for 1500 ms before the execution phase played. In the

307   final frame prior to shuttle contact, the video paused for 1500 ms. During the video, the

308   researcher read a statement that described the two phases of the movement. The statement

309   included when and where the kinematic differences occurred between serves, based upon the

310   kinematic data reported in Alder et al. (2014; see also Ryu et al., 2013).

311   In the instructional intervention during the second training session, participants viewed

312   a two-minute video that contained footage of the visual search behaviour of an Olympic level

313   player completing the same temporal occlusion test. During the video, the researcher read a

314   statement that described the visual search behaviours adopted by the Olympian. He exhibited

315   behaviours consisting of few fixations of a longer duration upon areas where between-shot

316   kinematic differences were located (Alder et al., 2014). Subsequently, participants were

317   shown five trials of their own visual search from the pre-test. In the instructional intervention

318   during the final training session, the researcher read a statement providing information about

319   how to differentiate serve-types. The information was taken from a coaching manual

320 (Badminton World Federation, 2013), stating that the backswing determined depth, whereas

321 wrist angle determined direction.

322 Anxiety levels were manipulated in a different manner between the two groups during

323 each of the training sessions. At the start of each training session, an anxiety-inducing

324 statement was read to the HA group that stated their response accuracy score from the last

325 session was in the bottom 20% of participants within their group and that was the reason for

326 the training. In contrast, the LA group was informed that the training was purely for research

327 purposes. After the first block of 12 trials in each intervention, the HA group were read

328 another anxiety-inducing statement stating that they remained in the bottom 20% for response

329 accuracy in their group. During training, the coach attempted to induce greater anxiety by

330 intermittently informing the HA group that their performance was not at the required level

331 and that they needed to improve. Both training groups completed the MRF-3 in each

332 intervention after the first 12 trials of the temporal occlusion test, but for the HA group this

333 occurred after the anxiety-inducing statement that directly followed the first 12 trials.

334 **Statistical analysis**

335 For the training phase, RA, cognitive anxiety and mental effort were analysed

336 separately using 2 Group (HA, LA) x 3 Training sessions (Training 1, Training 2, Training 3)

337 ANOVAs, where the first factor was between-participants and the second factor a repeated

338 measure. RA and mental effort in the video-based pre- and post-tests were analysed in

339 separate 3 Group (HA, LA, CON) x 2 Test Sessions (Pre, Post) x 2 Anxiety Condition (Low,

340 High) ANOVAs, with repeated measures on the last two factors. ACT predictions focus on

341 cognitive anxiety, so data from the MRF-3 'worried' subscale that measures cognitive

342 anxiety was analysed in a 3 Group (HA, LA, CON) x 2 Test sessions (Pre, Post) x 2 Anxiety

343 condition (High, Low) ANOVA, with repeated measures on the last two factors. RA and

344 mental effort in the field-based sessions were analysed in separate 3 Group (HA, LA, CON) x

345 2 Test sessions (Pre, Post) ANOVA, with repeated measures on the last factor.

346   The number of fixations employed in the field-based tests were analysed using a 3

347 Group (HA, LA, CON) x 2 Test Sessions (Pre, Post) ANOVA, with repeated measures on the

348 last factor, whereas number of fixations in the video-based tests were analysed using the

349 same type of ANOVA with 2 Anxiety Condition (High, Low) as an additional repeated

350 measure. Alder et al. (2014) examined the ability of expert and novice badminton players to

351 anticipate the same serve task as used in the current experiment. Participants in their

352 experiment made two fixations on average during the task and initial inspection of our data

353 revealed a similar mean value. In Alder et al. (2014) differences between groups in visual

354 search duration were found for the final fixation, but not for the preceding fixation.

355 Therefore, in the current experiment, fixation duration was analysed for the final fixation

356 only. Final fixation duration in the video-based tests was analysed using a 3 Group (HA, LA,

357 CON) x 2 Test sessions (Pre, Post) x 2 Anxiety Condition (Low, High) ANOVA, with

358 repeated measures on the last two factors. Final fixation duration in the field-based tests were

359 analysed using a 3 Group (HA, LA, CON) x 2 Test Sessions (Pre, Post) ANOVA, with

360 repeated measures on the last factor.

361   Any significant interactions were analysed using Tukey's Honestly Significant

362 Difference. Bonferroni comparisons were used for main effects involving more than two

363 variables. Partial eta-squared was used to report effect size. Intra-reliability observer checks

364 were conducted on the visual search data using the test-retest method, with the data from a

365 HA participant (93% reliability), LA participant (95% reliability) and a CON participant

366 (98% reliability) being re-analysed and found to be objective. For all statistical tests, the

367 alpha level for significance was .05.

368   `

369   **Results**

370   **Training phase**

371   **Anxiety and mental effort.** Table 1 shows cognitive anxiety and mental effort scores

372   during the training phase. There were significant main effects of Group for both cognitive

373   anxiety, $F(1, 18) = 25.69$, $p < .01$, $\eta_p^2 = .59$, and mental effort, $F(2, 36) = 19.29$, $p = .03$, η_p^2

374    $= .52$. As expected, the HA group reported greater cognitive anxiety and mental effort during

375   the training intervention when compared to the LA. There was no Training Session main

376   effect for cognitive anxiety, $F(2, 36) = 1.32$ $p = .91$, $\eta_p^2 = .04$, or mental effort, $F(2, 36) =$

377   1.93 $p = .71$, $\eta_p^2 = .08$. There was no Group x Training Session interaction for cognitive

378   anxiety, $F(2, 36) = 1.45$, $p = .25$, $\eta_p^2 = .08$, or mental effort, $F(2, 36) = 0.12$, $p = .81$, η_p^2

379    $< .01$

380   **Response accuracy**. There were no significant Group, $F(1, 18) = 3.54$, $p = .67$, η_p^2

381    $= .06$, or Testing Session main effects, $F(2, 36) = 7.53$, $p = .37$, $\eta_p^2 = .07$. There was a

382   significant Group x Training Session interaction, $F(2, 36) = 4.59$, $p = .02$, $\eta_p^2 = .21$. *Post hoc*

383   tests showed that in the first session there were no between-group differences ($p = .32$). In the

384   second training session, the LA group improved the accuracy of anticipation judgement

385   compared to the first training session ($p = .03$), whereas the HA group did not ($p = .12$). In

386   the third training session, there were no between-group differences ($p = .28$), but both HA

387   and LA groups had increased the accuracy of anticipation judgement compared to the first

388   (HA $p = .03$; LA $p = .04$) and second training session (HA $p = .04$; LA $p = .02$).

389   **Pre- and post-test**

390   **Anxiety and mental effort**. Table 2 shows cognitive anxiety and mental effort in the

391   pre- and post-test. There were significant main effects for Anxiety Condition for both

392   cognitive anxiety, $F(1, 27) = 62.41$, $p < .01$, $\eta_p^2 = .69$, and mental effort, $F(1, 27) = 13.32$, p

393    $< .01$, $\eta_p^2 = .33$. As predicted, there was greater cognitive anxiety and mental effort in high-

394 compared to low-anxiety conditions. For cognitive anxiety, there was no Group, F (2, 27) =

395 2.48, $p = .11$, $\eta_p^2 = .16$, or Testing Session, F (1, 27) = 7.55, $p = .09$, $\eta_p^2 = .22$, main effects.

396 The interactions were not significant between Group x Testing Session, F (2, 27) = 0.42, p

397 $= .66$, $\eta_p^2 = .03$, Anxiety Condition x Group, F (2, 27) = 0.27, $p = .77$, $\eta_p^2 = .02$, Testing

398 Session x Anxiety Condition, F (1, 27) = 0.98, $p = .33$, $\eta_p^2 = .04$, or Testing session x Anxiety

399 condition x Group, F (2, 27) = 0.91, $p = .42$, $\eta_p^2 = .06$. For mental effort, there were no main

400 effects for Group, F (2, 27) = 2.19, $p = .13$, $\eta_p^2 = .14$, or Testing Session, F (1, 27) = 4.21, p

401 $= .06$, $\eta_p^2 = .36$. The interactions were not significant between Group x Testing Session, F (2,

402 27) = 2.23, $p = .13$, $\eta_p^2 = .14$, Anxiety Condition x Group, F (2, 27) = 0.07, $p = .93$, $\eta_p^2 <$

403 0.01, Testing Session x Anxiety Condition, F (1, 27) = 1.13, $p = .16$, $\eta_p^2 = .12$, and Testing

404 session x Anxiety condition x Group, F (2, 27) = 1.57, $p = .22$, $\eta_p^2 = .12$.

405 **Response accuracy.** Figure 2 shows RA in the video-based sessions as a function of

406 Group, Test Session and Anxiety Condition. There were significant main effects for Group, F

407 (2, 27) = 3.59, $p = .04$, $\eta_p^2 = 0.21$, Test session, F (1, 27) = 43.38, $p < .01$, $\eta_p^2 = 0.62$, and

408 Anxiety Condition, F (1, 27) = 21.34, $p < .01$, $\eta_p^2 = 0.44$. As expected, RA was greater for

409 HA and LA compared to CON, in the post- compared to pre-test, and in the low- compared to

410 high-anxiety conditions. There were two-way interactions for Group x Testing session, F (2,

411 27) = 11.29, $p < .01$, $\eta_p^2 = 0.45$, Anxiety condition x Group, F (2, 27) = 3.75, $p = .04$, $\eta_p^2 =$

412 0.22, and Testing session x Anxiety condition, F (1, 27) = 6.33, $p = .02$, $\eta_p^2 = 0.19$. There

413 was a significant three-way Group x Test Session x Anxiety Condition interaction that

414 explained the data, F (2, 27) = 3.71, $p = .04$, $\eta_p^2 = 0.22$. *Post hoc* tests showed that in the low-

415 anxiety pre-test there were no differences in RA between groups (*p's* > .5). In the high-

416 anxiety pre-test, the RA of each group was lower compared to their low anxiety pre-test (*p's*

417 < .02).

418

419   In the low anxiety post-test, the LA group and the HA group had significantly greater RA

420   than both their pre-test scores (LA $p = .03$; HA $p = .04$) and the CON group (LA $p = .01$; HA

421    $p = .02$), whereas there was no difference in RA between the LA and HA group ($p = .38$).

422   However, in the high-anxiety post-test, as predicted, the HA group had significantly greater

423   RA compared to the LA ($p = .04$) and the CON ($p = .02$) groups.

424   Figure 3 shows RA in the field-based sessions. There were significant main effects for

425   Group, $F(2, 27) = 6.15$, $p = .01$, $\eta_p^2 = 0.31$, and Test Session, $F(1, 27) = 143.61$, $p < .01$, η_p^2

426    $= 0.84$. RA was greater for HA and LA compared to CON and in the post- compared to pre-

427   test. There was a significant Group x Test Session interaction, $F(1, 27) = 5.74$, $p < .01$, $\eta_p^2 =$

428   0.29. *Post hoc* tests revealed that in the pre-test there was no between-group difference in RA

429   (*p's* $> .3$). However, in the post-test, both the LA group ($p = .04$) and HA group ($p = .03$) had

430   greater RA compared to their pre-test, whereas the CON group did not ($p = .32$).

431   **Visual search behaviour.** Table 3 shows the number of fixations and duration of final

432   visual fixation in the video-based test, whereas Table 4 shows the number of fixations and

433   duration of final fixation (ms) in the field-based test. For number of fixations, there were no

434   main effects for Group, $F(2, 27) = 0.34$, $p = .21$, $\eta_p^2 = .03$, Test Session, $F(1, 27) = 5.39$, p

435    $= .15$, $\eta_p^2 = .36$, or Anxiety Condition, $F(1, 27) = 3.13$, $p = .08$, $\eta_p^2 = .11$, albeit the latter

436   approached significance with fewer fixations under low- compared to high-anxiety

437   conditions. There were no two-way interactions between Group x Testing Session, $F(2, 27)$

438    $= 3.26$, $p = .09$, $\eta_p^2 = .19$, Anxiety Condition x Group, $F(2, 27) = 3.35$, $p = .11$, $\eta_p^2 = .19$, and

439   Testing Session x Anxiety Condition, $F(1, 27) = 7.45$, $p = .09$, $\eta_p^2 = .22$. However, each of

440   these two-way interactions approached significance because: (i) HA used less fixations in the

441   post- compared to pre-test ($p = .09$), whereas there were no differences between tests for LA

442   ($p = .32$) and CON ($p = .21$); (ii) LA ($p = .08$) and CON ($p = .13$) used more fixations in the

443   high- compared to low-anxiety conditions, whereas HA demonstrated no difference between

444   anxiety conditions ($p = .43$); and (iii) more fixations occurred in the high-anxiety pre-test

445   compared to the low-anxiety post-test ($p = .07$), but there was no difference between anxiety-

446   conditions elsewhere ($p = .32$). The Group x Testing session x Anxiety condition interaction

447   was not significant, $F (2, 27) = 0.89$, $p = .42$, $\eta_p^2 = .06$.

448   For final fixation duration in the video-based sessions, there was no main effect for

449   Group, $F (2, 27) = 2.59$, $p = .09$, $\eta_p^2 = .16$, although this approached significance because

450   final fixation duration for CON was shorter compared to LA ($p = .12$) and HA ($p = .09$)

451   groups, whereas there was no difference between HA and LA groups ($p = .42$). There was a

452   main effect for Test, $F (1, 27) = 5.52$, $p = .03$, $\eta_p^2 = .17$, where final fixation duration was

453   longer in the post- compared to pre-test. There was a main effect for Anxiety Condition, $F (1,$

454     $27) = 19.19$, $p < .01$, $\eta_p^2 = .42$, showing final fixation duration was shorter in the high-

455   compared to low-anxiety condition. There was no Group x Testing Session interaction, $F (2,$

456     $27) = 1.69$, $p = .21$, $\eta_p^2 = .11$, Anxiety condition x Group, $F (2, 27) = 0.39$, $p = .42$, $\eta_p^2 = .07$,

457   or Testing session x Anxiety condition, $F (1, 27) = 1.89$, $p = .19$, $\eta_p^2 = .02$, interactions. The

458   Testing session x Anxiety condition x Group interaction was not significant, but approached

459   significance, $F (2, 27) = 1.65$, $p = .11$, $\eta_p^2 = .21$. In the high-anxiety post-test, final fixation

460   duration for HA was not different to the low-anxiety post-test ($p = .27$), whereas it was

461   shorter for LA ($p = .09$) and CON ($p = .12$) compared to the low-anxiety post-test, and not

462   different elsewhere.

463   In the field-based sessions, the number of fixations did not differ as function of Group,

464     $F (2, 27) = 0.07$, $p = .94$, $\eta_p^2 < .01$, or Test Session, $F (1, 27) = 0.60$, $p = .45$, $\eta_p^2 = .02$, nor

465   was the Group x Test Session significant, $F (2, 27) = 0.13$, $p = .88$, $\eta_p^2 = .01$. For duration of

466   final fixation in the field-based sessions, there was no main effects for Group, $F (2, 27) =$

467   0.92, $p = .34$, $\eta_p^2 < .01$, or Testing Session, $F (1, 27) = 2.87$, $p = .11$, $\eta_p^2 = .09$, although the

468   latter approached significance with longer final fixation durations in the post- compared to

469   pre-test. There was no Group x Testing Session interaction, $F(2, 27) = 2.49$, $p = .12$, η_p^2

470    $= .16$.

Discussion

472   We examined the training of anticipation judgement and visual search behaviours in

473   international-level badminton players under high- compared to low-anxiety conditions and

474   the extent to which any improvement in performance was retained under high-anxiety

475   conditions and a transfer test a field-based condition. The training intervention led to an

476   increase in the accuracy of anticipation judgements for both LA and HA groups in the post-

477   compared to the pre-tests relative to a control group. Moreover, final fixation duration was

478   significantly longer in the post- compared to pre-test. In the high-anxiety post-test, the

479   accuracy of anticipation judgements for the LA group decreased when compared to the low-

480   anxiety post-test. In contrast, the HA group maintained the accuracy of their anticipation

481   judgements across anxiety conditions in the post-test. In addition, final fixation duration for

482   the HA group was not significantly different between the high- and low-anxiety post-test,

483   whereas for the LA and CON groups there was a trend ($p = .11$) towards a shorter final

484   fixation duration in the high- compared to low-anxiety post-test. Other measures of

485   professing efficiency (mental effort, number of fixations) did not differentiate groups across

486   tests.

487   As predicted, in the high-anxiety post-test, the anticipation accuracy of the HA group

488   did not differ from their low-anxiety post-test. However, for the LA and CON groups, lower

489   anticipation accuracy scores were reported in the high- compared with low-anxiety post-test.

490   Given the lack of differences in RA between the three groups in the pre-test, the post-test data

491   supports previous research (e.g., Oudejans & Pijpers, 2009) showing that training under high-

492   anxiety leads to greater retention of performance under subsequent high-anxiety conditions,

493   when compared to low-anxiety training. Findings demonstrate that this effect extends to

494   anticipation judgements in sport. ACT predicts that high-anxiety leads to an increase in

495   effort, thus a decrease in processing efficiency, in an attempt to limit the potentially

496   detrimental effects of anxiety on performance outcome (Eysenck et al., 2007). In support of

497   this prediction, the HA group demonstrated greater mental effort during training compared to

498   the LA group and mental effort was generally greater for both groups under high- compared

499   to low-anxiety conditions. Findings supports ACT and previous research (e.g., Wilson et al.,

500   2007) showing that high-anxiety results in a reduction in performance efficiency as evidenced

501   by increased effort in an attempt to maintain performance outcome (Murray & Janelle, 2003;

502   Wilson et al., 2009).

503   As expected, the HA group maintained performance outcome between the high- and

504   low-anxiety conditions in the post-test and this was underpinned by a lack of difference in

505   visual search behaviours between anxiety conditions. The high-anxiety training resulted in

506   the HA group being able to maintain final fixation durations in the high-anxiety post-test

507   when compared to the low-anxiety post-test. In contrast, data suggests that in the high-

508   anxiety post-test the LA and CON groups demonstrated final fixation durations which were

509   shorter compared to the low-anxiety post-test along with a reduction in performance

510   outcome, when compared to the low-anxiety post-test and the HA group, albeit this

511   interaction only approached significance ($p = .11$). These findings support previous research

512   showing that longer final fixations coupled with fewer fixations characterises expert

513   performance in racket sports (e.g., Alder et al., 2014), perhaps by allowing time for maximal

514   information processing to occur (Mann et al., 2007) and limiting the opportunity for

515   distracting stimuli to interrupt performance (Wilson et al., 2007). It extends previous research

516   (e.g., Oudejans & Pijpers, 2009) by showing that training should expose individuals to

517   competition-like stressors, allowing them to develop more effective visual search behaviours

518   to counter the negative effects of high-anxiety and improve performance in those conditions.

519   It was expected that performance improvements established in the video-based training

520   would transfer to a field-based condition. Our data support this hypothesis with both training

521   groups reporting higher accuracy scores in the field-based post-test when compared to the

522   pre-test and CON group. Findings support previous research (e.g., Farrow & Abernethy,

523   2002; Ryu et al., 2013; Williams et al., 2002) showing that training interventions involving

524   representative tasks that simulate the performance environment are an effective method for

525   developing anticipation judgement that transfers to the field. During the training phase, the

526   training groups were likely able to refine their task-specific skills and knowledge allowing

527   them to improve the processing of information, which led to a greater transfer of the

528   developed behaviours from the video- to field-based sessions. Moreover, as expected, the

529   training phase led to a general increase in the accuracy of anticipation judgements on the

530   video-based post-test. The training groups demonstrated more accurate anticipation

531   judgements in the low-anxiety post-test compared to the pre-test and CON, whereas the CON

532   did not improve. These findings support previous research showing training interventions

533   highlighting the most effective visual search behaviour are an effective method for

534   developing anticipation judgement (Abernethy et al., 2012; Ryu et al., 2013; Smeeton et al.,

535   2005). The majority of research in this area has focused upon developing anticipation

536   judgement in novice (Abernethy et al., 2007) or intermediate level athletes (Smeeton et al.,

537   2005; for exceptions see Causer et al., 2011). Our data extends this work by showing that

538   international-level athletes can benefit from simulation training and it can lead to significant

539   improvements in anticipation judgments.

540   In accordance with ACT, processing efficiency was expected to generally reduce under

541   high-compared to low-anxiety conditions (Eysenck et al., 2007). In line with these

542   predictions, high-anxiety conditions generally lead to greater mental effort when compared to

543   the low-anxiety conditions. In addition, under high-anxiety conditions, final fixation duration

544   was generally shorter when compared to low-anxiety conditions. However, data for the

545   number of fixations contradict this prediction, as there was no effect of anxiety. These

546   contradictory findings could possibly be attributed to the constraints of the task. The

547   badminton serve has a short movement duration and short phases within the movement (e.g.,

548   execution phase of 1,900 ms duration, see Alder et al., 2014). Therefore, the duration of the

549   task may not have provided sufficient time for the differences in fixation frequency normally

550   found for anxiety and for fixation duration differences to become apparent. Regardless, the

551   HA group was able to maintain longer final fixation durations between the high- and low-

552   anxiety post-tests, whereas the durations became shorter for the LA and CON group in the

553   high- compared to low-anxiety post-test, albeit this interaction only approached significance

554   ($p = .11$). A potential reason for this three-way interaction for final fixation duration failing to

555   reach significance may be lower statistical power due to the sample size in this study ($n = 10$

556   per group). However, the sample size employed was representative of those used in previous

557   research in this area (e.g. Savelsbergh et al., 2002; Smeeton et al., 2005) and the population

558   size of truly expert athletes from which the sample was drawn is relatively small.

559   A limitation to these type of studies is the indirect method of measuring attention,

560   usually by self-report measures or visual search behaviours. This makes it difficult to

561   ascertain how attention is allocated or the specific strategies individuals use to overcome

562   working memory constraints. For example, one explanation for the between-group difference

563   in anticipation judgements could be related to differences in attentional resource delegation

564   strategies acquired from the different training protocols. That is, through exposure to high-

565   anxiety training, the HA group may have acquired the ability to delegate attentional resources

566   more efficiently and effectively under later high-anxiety conditions. Conversely, the low-

567   anxiety training did not allow the LA group to develop these strategies. However, without a

568   direct measure of attention allocation we can only postulate as to the effect that training has

569 on attentional strategies. Future research is needed to use more direct measures of attention

570 allocation to determine the differences in attention strategies developed by these training

571 protocols. Furthermore, researchers should examine if these attentional changes lead to

572 changes in brain activation and to adaptation of memory structures used by these highly

573 skilled athletes. In summary, a video-based training intervention under high-anxiety

574 conditions led to better retention and transfer of learning to subsequent test conditions

575 involving high-anxiety when compared to low-anxiety training conditions. In contrast,

576 training under low-anxiety conditions led to decrements in anticipation performance and a

577 suggested change in visual search behaviour under high-compared to low-anxiety retention

578 tests. It appears that exposing athletes to high-anxiety during training allows them to modify

579 their behaviours in order to maintain performance in future high-anxiety conditions. In

580 addition, the video-based training intervention improved the accuracy of anticipation

581 judgement, with these positive effects transferring to the field setting.

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695

Figures

1. Pre-test
Low-anxiety laboratory ($n = 36$ trials)
High-anxiety laboratory ($n = 36$ trials)
Field-based session ($n = 18$ trials)

2. Training phase

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

3. Post-test

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

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

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

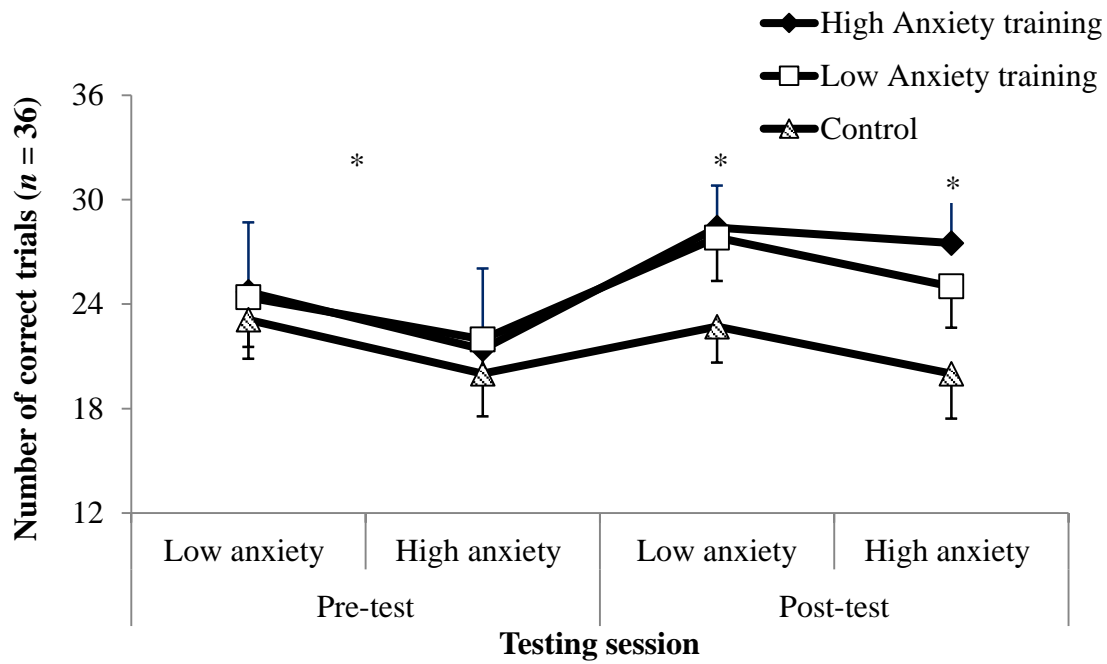**Figure 1: Timeline of experimental process**

699

700   Figure 2. Mean (SD) response accuracy (number of trials) for the three groups on the video-

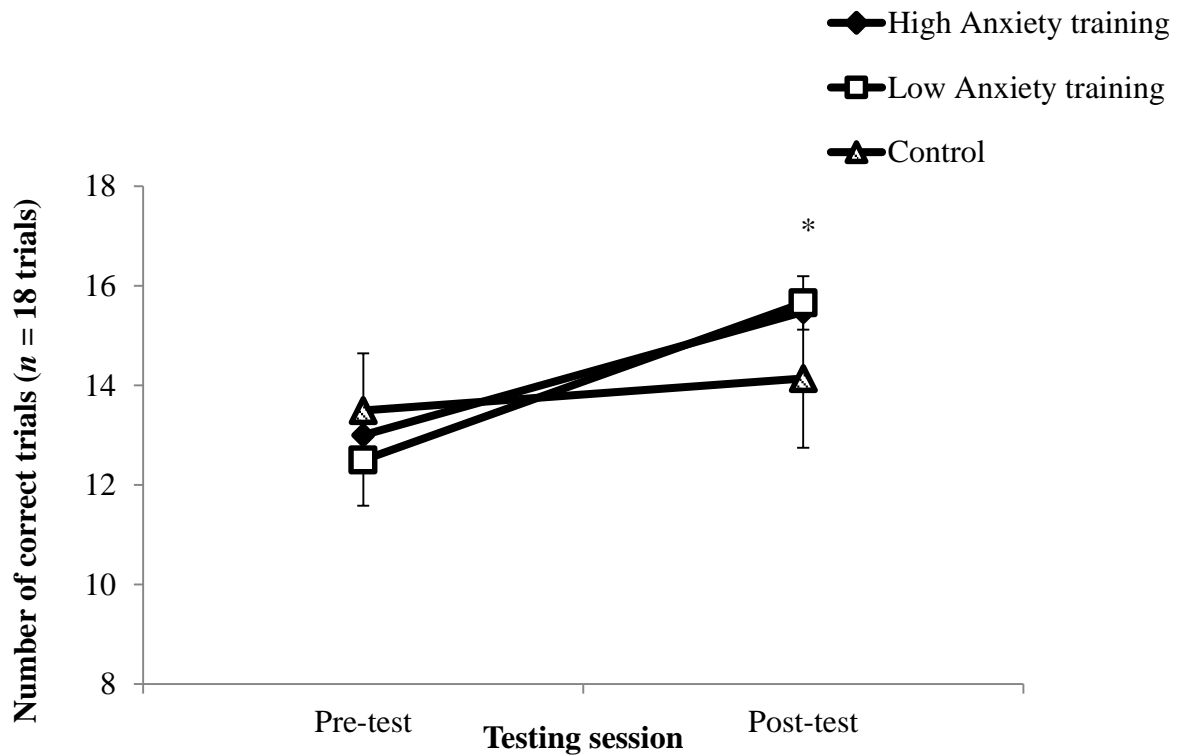701   based task across the pre-, training, and post-tests.

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704   Figure 3. Mean (SD) response accuracy (number of trials) for the three groups on the field-

705   based task in the pre- and post-tests.

706 **Table 1. Mean (SD) scores for cognitive anxiety from the MRF-3 and mental effort from**
707 **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)

708

709 **Table 2. Mean (SD) scores for the cognitive anxiety subscale of the MRF-3 and for mental**

710 **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)

711

712 **Table 3. Mean (SD) number of fixations and duration of final visual fixation (ms) in the**
713 **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	2.4	2.1	1.9	1880	1741	1983	1851
	(0.4)	(0.3)	(0.5)	(0.3)	(358)	(215)	(44)	(104)
LA	1.9	2.5	2.2	2.1	1840	1822	2074	1796
	(0.4)	(0.6)	(0.5)	(0.3)	(159)	(183)	(180)	(199)
CON	2.1	2.6	2.2	2.1	1886	1633	1890	1615
	(0.2)	(0.3)	(0.3)	(0.3)	(154)	(299)	(110)	(319)

714

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)

715

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.