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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.

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 shoot 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.

198

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, $F(2, 36) = 19.29, p = .03, \eta_p^2$
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, $F(2, 36) = 0.12, p = .81, \eta_p^2$
379 $< .01$

380 **Response accuracy.** There were no significant Group, $F(1, 18) = 3.54, p = .67, \eta_p^2$
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, $F(2, 27) = 2.49, p = .12, \eta_p^2$
470 $= .16$.

471 **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 processing 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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584 The authors declare no conflicts of interest.

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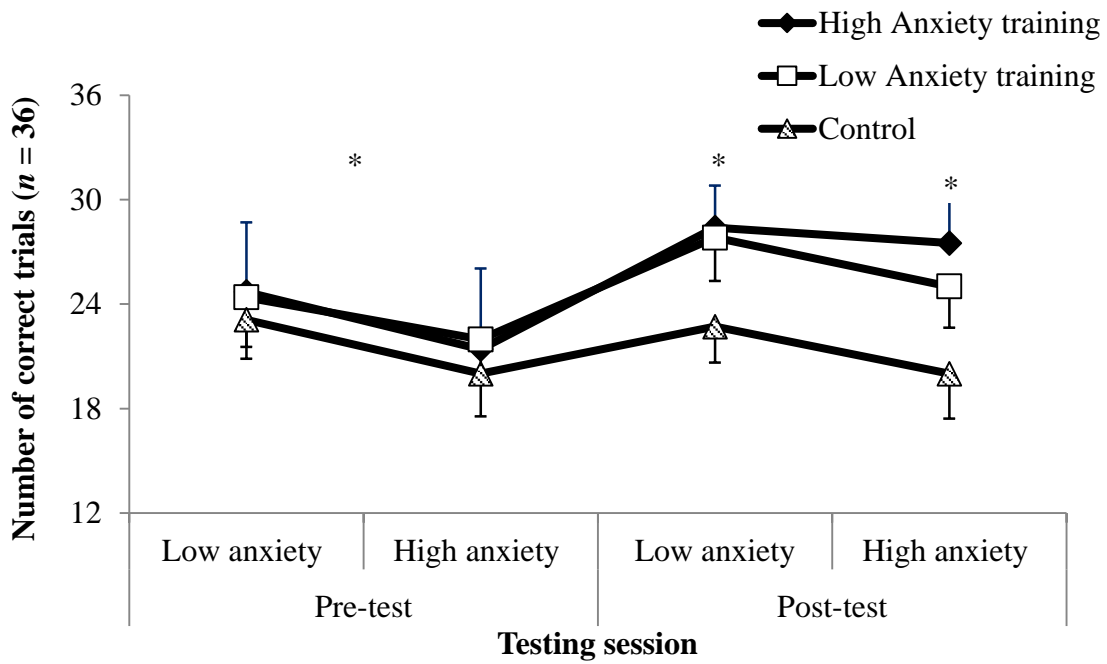
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Figures

<u>1. Pre-test</u>	
Low-anxiety laboratory (<i>n</i> = 36 trials)	
High-anxiety laboratory (<i>n</i> = 36 trials)	
Field-based session (<i>n</i> = 18 trials)	
<u>2. Training phase</u>	
Intervention 1	<ol style="list-style-type: none"> 1. Temporal occlusion test and feedback (<i>n</i> = 12 trials) 2. Manipulated videos and info on kinematics of movement 3. Temporal occlusion test and feedback (<i>n</i> = 12 trials) 4. MRF-3 and RSME
Intervention 2	<ol style="list-style-type: none"> 1. Temporal occlusion test and feedback (<i>n</i> = 12 trials) 2. Examples of “gold standard” visual search 3. Temporal occlusion test and feedback (<i>n</i> = 12 trials) 4. MRF-3 and RSME
Intervention 3	<ol style="list-style-type: none"> 1. Temporal occlusion test and feedback (<i>n</i> = 12 trials) 2. Examples of own visual search from pre-test 3. Temporal occlusion test and feedback (<i>n</i> = 12 trials) 4. MRF-3 and RSME
<u>3. Post-test</u>	
Low-anxiety laboratory (<i>n</i> = 36 trials)	
High-anxiety laboratory (<i>n</i> = 36 trials)	
Field-based session (<i>n</i> = 18 trials)	

Figure 1: Timeline of experimental process



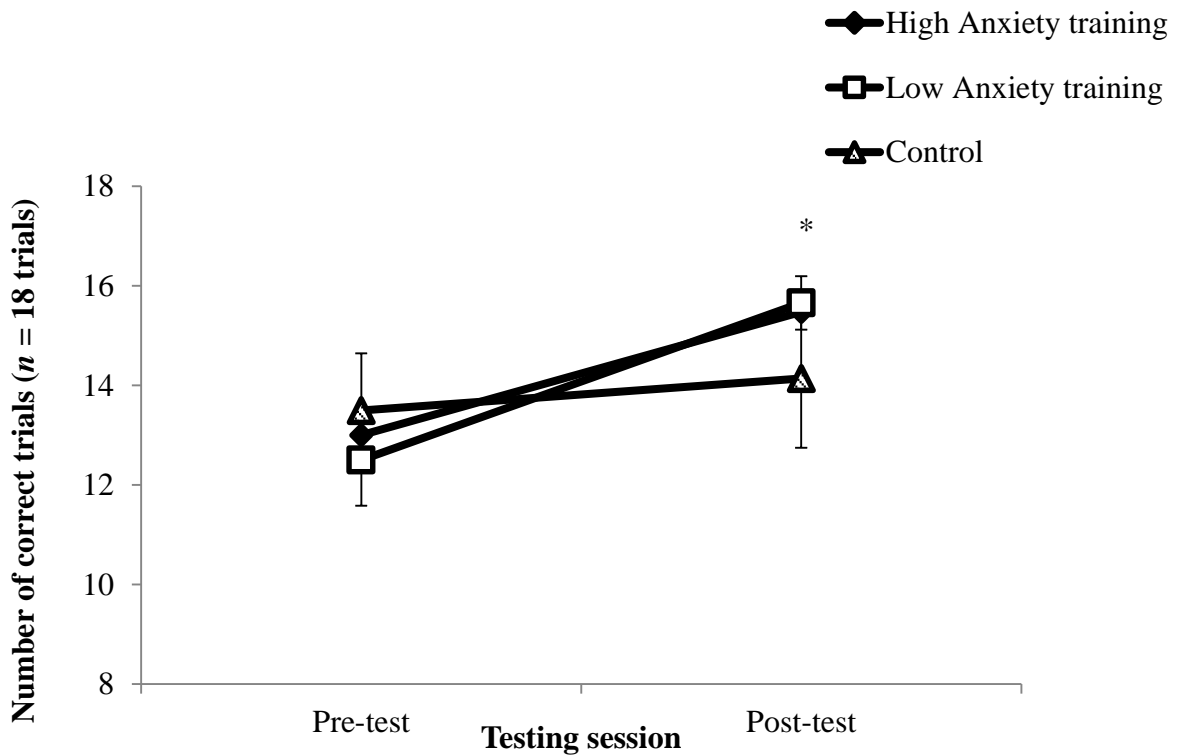
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700 Figure 2. Mean (SD) response accuracy (number of trials) for the three groups on the video-

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

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703

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.**

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

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.