

1 **ABSTRACT**

2 **Objective:** The visibility of the pink ball used in day/night Test cricket has been under scrutiny,
3 with recent research suggesting cricketers find the pink ball less visible at dusk under
4 floodlights. With increasing interest in this match format, this study sought to investigate elite
5 umpires' opinions pertaining to the visibility of the pink cricket ball during day/night matches.

6 **Design:** Purposeful sampling of a cross-section of elite umpires with experience adjudicating
7 matches played using a pink cricket ball.

8 **Method:** Twenty-seven international/first-class umpires completed a questionnaire consisting
9 of Likert scale and free text responses covering perceptions of the pink cricket ball, with a
10 particular emphasis on visibility.

11 **Results:** The pink ball when viewed at night under floodlights was rated as being significantly
12 more visible than the red ball during natural lighting ($p < 0.050$). Umpires who actively
13 participated in training reported a significantly higher rating of the visibility of the pink ball
14 (mean -3.14) at night under floodlights compared to those who didn't (mean $p = 0.010$). No
15 significant difference was reported in visibility in natural light or dusk under floodlights. Free
16 text responses ($n=10$) revealed the following themes: use of eyewear (coverage 0.30), and
17 adjustment to positioning (coverage 0.20) to improve visibility of the pink ball.

18 **Conclusion:** Umpires report the visibility of the pink ball is equal to the red in natural light and
19 at dusk but is significantly better at night. Preference for the pink ball is likely due to the
20 predominantly perceptual nature of visual tasks performed by umpires.

21 **1. INTRODUCTION**

22 In the lead up to India's inaugural International day/night Test cricket match, International
23 Cricket Council (ICC) umpire Sundaram Ravi was quoted on the difficulties faced by cricket
24 umpires when officiating in matches during dusk using a pink ball.

25

26 *"We [cricket umpires] found it slightly difficult to sight the ball during the twilight. When the*
27 *floodlights are taking over. That time we would focus a little harder to sight the ball. We*
28 *concentrated a little extra during that time"*¹

29

30 A decline in the number of spectators attending Test cricket matches² has led to the
31 introduction of day/night Test cricket, where play starts late in the day under natural light and
32 continues to be played under floodlights through dusk and into the night. To increase the
33 visibility of the ball used during the night conditions, Australian ball manufacturer Kookaburra
34 created prototypes of different coloured cricket balls. Upon advice from television companies³,
35 and after gaining approval from the ICC, a (fluorescent) pink cricket ball was chosen. Following
36 expressions of concern by some players^{4,5} about player performance and safety^{5,6},
37 Kookaburra changed the colour of the seam (two rows of stitching running down the centre of
38 the ball) from the original green/white to black⁷.

39

40 A recent study investigated the opinions of cricketers with experience playing in pink ball
41 matches⁸, with the results showing that players report difficulties with the visibility of the ball
42 in particular at dusk under floodlights, both when batting and fielding. Visibility of the pink ball
43 was also reported to be poorer when batting against pace (faster) deliveries compared to spin
44 (slower) deliveries. Adie and Arnold^{9,10} have suggested that the visibility of the pink ball is
45 impacted particularly at dusk due to the low luminance contrast of the ball against the sky,
46 resulting in a reduced ability to perceive motion. The authors also presented preliminary
47 evidence that visibility may be improved with the use of rose-tinted lenses (Oakley Prizm Golf).
48 When batting and fielding, cricketers acquire and process visual information, with success
49 often relying on the ability to pick-up ball-flight information as early as possible^{11,12,13}. Although
50 a high level of visual acuity may not necessarily be vital for the identification of optimal
51 information^{13,14}, a high level of contrast sensitivity presumably is^{9,10}.

52

53 Cricket umpires officiate from two alternating positions during a cricket match, and importantly,
54 the visual demands from those two positions differ. Umpires interchange their position after
55 every six legal deliveries between the 'bowler's (non-striking) end' and 'square leg' (roughly
56 22 yards from the batsman's legs orthogonal to the direction of the pitch). Umpires at the
57 bowler's end are, amongst other tasks, required when making leg-before-wicket decisions to
58 make predictive judgements about whether a ball that hits the batter may have gone on to hit
59 the stumps^{15,16,17}. The role of the umpire at the square leg position differs, instead requiring
60 them to track a ball from a side-on position to determine where the ball passes the batter, and
61 whether the batter completes the run safely before the ball strikes the stumps. Accordingly, it
62 is important to establish the degree to which the visibility of the pink ball is influenced when
63 umpiring in each of those two positions.

64

65 Umpires, just like players, also make decisions based on their identification of visual
66 information, yet there is neuropsychological evidence to suggest that the nature of the visual
67 information that umpires rely on might differ to that of players. The dual-pathway theory of
68 vision^{18,19} suggests that the nature of visual information relied on to control actions (information
69 in the dorsal pathway that is highly sensitive to motion and contrast) may be different to that
70 relied on for perceptual decisions (ventral pathway sensitive to acuity and colour). While
71 cricketers when batting likely rely on contributions from both the ventral and dorsal pathways
72 (i.e., respectively for initial visual cue pick-up through to the execution of an interceptive action
73 when attempting to strike the ball), cricket *umpires* would rely solely on the perceptual
74 pathway. More specifically, research suggests that coupled responses (subconscious)
75 required for the completion of an interceptive action involve dorsal processing, and non-
76 coupled (conscious) responses for perceptual actions originate from the ventral processing
77 pathway^{14,19}. Accordingly, it is possible the visual demands of players and umpires might vary,
78 and consequently the experiences of players viewing the pink ball might differ to umpires.
79 Another key difference between the role of players and umpires is that batters (and
80 some fielders positioned behind the batter) view the ball as it is looming towards them whereas
81 the umpire at the bowler's end views the ball with it looming away from them²⁰. The
82 complexities of the retinal image processing of motion in direction (MID) of a ball, and time to
83 collision processing²⁰ are exacerbated with the inclusion of an interceptive task. The direction
84 of the MID is a function of the ball's angular velocities and the resulting retinal images. This
85 further highlights the importance an interceptive act plays on the processing of visual
86 information. The umpire at the bowler's end must deal with looming of the opposite sign (away
87 from) but without time to collision processing.

88

89 One significant visual challenge faced in cricket is the diverse set of backgrounds participants
90 must track the ball against such as the sky, the crowd, the grass outfield, and the sight screens
91 (white in Test cricket). Although the backgrounds remain relatively constant across all Test
92 cricket venues, the changing light conditions alters the composition of the background. Any
93 alteration to the illumination or colour composition to the background the ball is viewed against,
94 will affect luminance contrast. Any change in the luminance contrast will in turn affect the
95 visibility of the target object. Accordingly, the visual demands of players and umpires might
96 differ, and consequently, the experiences of players viewing the pink cricket ball might differ
97 to umpires.

98

99 The aim of this study was to investigate professional cricket umpires' opinions regarding the
100 visibility of the pink cricket ball when adjudicating day/night cricket matches. The study
101 explored whether, as suggested from our research on players⁸ the period at dusk under
102 floodlights is the most challenging for visibility when compared to conditions experienced
103 during the day and at night. We hypothesized that umpires would report the pink cricket ball
104 to be visibly more challenging than the red ball while umpiring from both positions under all
105 three light conditions, with difficulties most pronounced when adjudicating at the bowler's end
106 due to the complexity of the visual tasks associated with officiating from this position.

107

108 **2. METHOD**

109 A cross-sectional survey study design was used to establish umpire perceptions of the visibility
110 of the pink cricket ball in day/night matches. The white ball used in limited (50 and 20) over
111 matches cannot currently be used in Test match cricket. The surface integrity and colour of
112 the ball degrades significantly prior to the 80 over life span required for use in Test cricket.
113 The white ball offers little to no contrast against the white clothing worn by Test cricketers. For
114 these reasons, the white ball was not considered for comparison within this study. A 27-item
115 questionnaire was initially developed by two researchers (PA, LW) based on previous
116 experience conducting a similar survey on elite cricketers⁸. The full research team (including
117 cricket coach [JJ] and umpire [JA]) then reviewed the survey in an iterative process with further
118 modifications made to the wording to make it suitable for umpires. The survey went through
119 two stages of review to establish validity prior to commencement of the study proper.
120 Individuals with knowledge of the sport (sports researchers, and cricket administrators)

121 reviewed the survey to ensure face validity and interpretability. Modifications were made
122 before the second stage, where the survey was sent to two elite umpires to determine whether
123 the questionnaire was sufficiently clear and straightforward to complete. They confirmed that
124 the length of the questionnaire was acceptable and that they experienced no difficulties with
125 the format or comprehensibility of the questions. The survey was available to the umpires for
126 one month and took between 15-20 minutes to complete. The study adhered to the tenets of
127 the Declaration of Helsinki. Ethical approval was obtained from the Faculty Research Ethics
128 Panel of Anglia Ruskin University.

129

130 Purposeful sampling was used towards the end of the 2018 English county cricket season to
131 recruit elite male cricket umpires (from the UK and internationally) who had experience
132 adjudicating pink ball cricket matches. The study consisted of 30 elite (international and first-
133 class) umpires recruited via the England and Wales Cricket Board (ECB), Cricket Australia
134 (CA), and the International Cricket Council (ICC). The data for the UK-based umpires were
135 collected at the ECB umpires' end of season meeting in paper form or using an online
136 questionnaire (Qualtrics). The international data were collected using the online questionnaire
137 circulated by an ICC elite panel member via email, and Australian umpires were invited via
138 the CA match officials' manager. Participants answered a combination of Likert scale and
139 closed questions, with free text comments allowing participants to expand on their responses.
140 The survey can be found in Appendix A1.

141

142 The final survey consisted of 4 sections, as follows:

143 Section A, addressing participant characteristics, contained questions about the participants'
144 officiating experience in matches and/or training with a pink ball. Further questions required
145 information regarding self-disclosure of any vision problems along with a personal rating of
146 their own distance vision (1 = very poor, to 10 = excellent).

147 Section B assessed *visibility of the pink ball under different lighting conditions*, with participants
148 asked to rate, on a 15-point Likert scale, the visibility of the pink ball under natural light, dusk
149 under floodlights, and night under floodlights when compared to the visibility of the red ball in
150 normal daylight conditions (control condition). Visibility was rated while umpiring from the
151 bowlers' end, and from the square leg position. Negative values (down to -7) indicated better
152 visibility with the pink ball while positive values (up to +7) indicated better visibility with the red
153 ball. A zero response indicated no difference in the visibility between the pink and red cricket
154 balls. Internal consistency for the Likert-scale questions was high (Cronbach's alpha = 0.766).
155 An example question in this section:

156 “On a scale from -7 (pink ball much easier to see) to +7 (red ball much easier to see),
157 with zero representing no difference, how visible is the pink ball compared to the red
158 ball while umpiring at THE BOWLER’S END in NATURAL AFTERNOON LIGHT?”

159

160 Section C evaluated *Approaches to umpiring with the pink ball* using a similar 15-point Likert
161 scale. Participants were asked to compare the visibility of the pink ball when umpiring pace
162 and spin bowling. An example question in this section:

163 “On a scale from -7 (pace bowling much more difficult) to +7 (spin bowling much more
164 difficult), with zero representing no difference, is the visibility of the pink ball more
165 difficult against PACE BOWLING or SPIN BOWLING?”

166

167 Negative responses (down to -7) indicated better visibility with pace bowling, with positive
168 responses (up to +7) indicating better visibility with spin bowling. Responses of 0 indicated no
169 difference in visibility between pace and spin bowling. Participants were asked if visibility
170 improves with time (yes/no/don’t experience), and whether visibility of the pink ball differs
171 between delivery types (full length, bouncers, slower balls, and normal length). Umpires were
172 also asked whether they made any changes to their umpiring style to accommodate the pink
173 cricket ball. Opinions were sought regarding the future direction of pink ball cricket, including
174 the potential use of an alternative ball colour, coloured clothing, and coloured sight screens.

175

176 Section D provided the opportunity for participants to offer any relevant information that had
177 not been covered in the survey.

178

179 Quantitative data were analysed using Statistical Package for Social Sciences (SPSS) version
180 26.0 (IBM Corp, 2019). Likert scale responses were treated as non-parametric ordinal data
181 and summarised using the median. A one-sample Wilcoxon signed-rank test was used to
182 determine whether values differed from zero. A paired-sample Wilcoxon signed-ranks test with
183 Bonferroni corrected p values (revised p -value of 0.025) was used to identify whether ratings
184 differed between lighting conditions. Categorical variables (yes/no) regarding acceptance of
185 the pink ball were described using frequencies.

186

187 To analyse the free text responses, content was initially analysed inductively to produce
188 themes that could then be used for categories in a content analysis^{8,21}. To become familiar

189 with the data the responses were first read and reread by the lead researcher with initial
190 observations noted. Next, features of the data were labelled and compiled to allow themes to
191 be identified. For content analysis, participant responses were broken into clauses, and each
192 clause was coded based on the themes generated. The five emergent themes generated
193 were: (i) *difficulties tracking pace deliveries due to ball speed*, (ii) *eyes do adjust with time*, (iii)
194 *continue with the pink ball*, (iv) *limited exposure makes it difficult to evaluate*, (v) *slight*
195 *adjustments made to positioning*. The coverage of each theme (the number of times the codes
196 associated with that theme appeared in the free text comments) was calculated; a maximum
197 possible coverage value being 1.0 (if all free text comments were to be associated with that
198 one theme). Themes with low coverage (less than 0.10) were not reported. This process was
199 conducted for each question by three members of the research team, with multiple codes
200 possible per response, for example a participant may mention both lighting conditions and the
201 background when asked about whether visibility differs facing different delivery types. To
202 ensure inter-rater reliability, the data were coded by the lead researcher and by an
203 independent researcher to reduce bias²². A Cohen's K was run to determine the level of
204 agreement between researchers, revealing a high level of agreement ($K=0.667$, $p<.001$).

205

206 **3. RESULTS**

207 **Section A - Umpire characteristics**

208 Participants ($n=27$; age 50.9, SD = 8.1yrs; range 32-57yrs) had all officiated in first-class or
209 International pink-ball matches (mean matches = 3.7, SD = 3.3, range 1-15) and so had
210 experience of umpiring under the full variety of lighting conditions. When asked if they had
211 previously undertaken any specific training in preparation for pink-ball matches, 11 umpires
212 (41%) reported no specific training and 16 umpires (59%) reported that they had attended
213 practice ('net') sessions using the pink ball in preparation for matches. Participants were asked
214 to rate their distance vision on a scale from 1 (very poor) to 10 (excellent); a mean rating of
215 9.5 (SD = 0.6) was recorded. One umpire reported having "mild colour blindness" (non-
216 specified self-reported CVD), although the participant passed the pre-season ECB vision
217 screening assessment.

218 **Section B - Visibility of the pink ball under different lighting conditions**

219 The median values of the umpires' ratings of the visibility of the pink cricket ball under different
220 lighting conditions (Figure 1) indicated that the visibility of the pink ball when viewed in natural
221 light and at dusk was no different to that when viewing the red ball under natural lighting (pink
222 ball in natural light, bowlers end median = 0, $z=-0.87$, $p=0.930$; pink ball at dusk, bowlers end
223 median 0, $z=-0.88$, $p=0.382$; pink ball in natural light, square leg median = 0, $z=-0.26$, $p=0.793$;
224 pink ball in natural light, square leg median = +1, $z=0.22$, $p=0.828$). However, the pink ball
225 when viewed at night under floodlights was rated as being more visible than the red ball is
226 during natural lighting (bowler's end median = -3, $z=-2.40$, $p=0.016$; square leg median = -3,
227 $z=-2.17$, $p=0.030$).

228

229 INSERT FIGURE 1 AROUND HERE

230

231 A paired samples Wilcoxon signed-ranks test revealed the pink ball to be more visible at night
232 under floodlights (median = -3) than at dusk under floodlights when viewed from the square
233 leg position (median +1, $z=-2.537$, $p=0.013$). No significant differences were found between
234 viewing at night under floodlights and in natural light for either viewing position ($p>0.025$;
235 Bonferonni corrected), or between any of the lighting conditions from the bowler's end.

236 An umpire's experience of using a pink ball did not alter their rating of the visibility of the pink
237 ball from either the bowler's end ($h=3.066$, $p=0.38$) or from square leg ($h=3.58$, $p=0.31$).

238

239 **Section C - Approaches to umpiring with the pink ball**

240 The pink ball was rated as being significantly less visible during the umpiring of pace bowling
241 when compared to umpiring spin bowling (median value=0, mean=-1.23, $z=-2.00$, $p=0.046$).
242 When asked to expand on the Likert responses, the main theme related to difficulties tracking
243 pace deliveries due to the speed of the ball ($n=20$, coverage 0.35). Responses relating to pace
244 bowling included:

245 "Spin bowling is obviously a lot slower, therefore easier to pick up and track"
246 (Participant 19), and "The ball moves faster so therefore more difficult to pick up!"
247 (Participant 22).

248

249 Participants were asked whether visibility improved over time if the pink ball was difficult to
250 see. From the responses received (n=23), six participants (26%) responded 'yes' that the pink
251 ball becomes gradually easier to see, eight (35%) responded 'no', and nine (39%) didn't
252 experience any problems seeing the pink ball. Free text responses (n=14) highlighted the
253 following theme: no problems experienced (coverage 0.29). Example responses included:

254 "I never really noticed a big difference with the pink ball" (Participant 24), "the pink ball
255 is a bright pink, it's not a dull colour, so I didn't notice any real change" (Participant 9).

256

257 Participants were asked if, when umpiring under floodlights, the visibility of the pink ball varied
258 depending on the delivery type. From the responses received (n=26), 11 participants (42%)
259 replied that visibility did depend on the delivery type, 15 participants (58%) responded that it
260 did not. Free text responses (n=12) provided the following themes: short deliveries being more
261 difficult (coverage 0.33); and full deliveries more difficult (coverage 0.25). Example responses
262 included:

263 "Short pitched deliveries are more difficult to pick up" (Participant 19), "Short balls are
264 often more difficult from side on as the angles are more steep" (Participant 22), and "I
265 believe that fuller deliveries are more difficult to pick up by both batsmen and umpires"
266 (Participant 13).

267

268 Participants were then asked if they have changed anything about the way they go about their
269 umpiring to accommodate the pink ball. From the responses (n=26), six reported that they did
270 make changes to accommodate the pink ball (23%), and 20 reported they did not make any
271 changes (77%). Free text responses (n=10) revealed the following themes: use of eyewear to
272 help (coverage 0.30), adjustment to positioning (coverage 0.20), and not enough exposure to
273 warrant changing anything (coverage 0.20). Responses included:

274 "I wear Oakley prism glasses" (Participant 15), "Ball tracking as mentioned above.
275 Standing back a bit further at dusk" (Participant 8), "I came closer at square leg to try
276 and pick the ball up better from side on" (Participant 17), and "We do very few games
277 so why would I change my routines?" (Participant 22), "Not yet - don't have enough
278 pink ball experience yet to figure out what the best solution would be" (Participant 15).

279

280 When asked if a different coloured ball would be preferable to using the pink ball in day/night
281 matches (n=24), nine participants responded yes (38%), with 15 answering no (62%). Free

282 text responses (n=18) highlighted two main themes/suggestions; Continue with the pink ball
283 (coverage 0.39), and white is more visible under artificial lighting (coverage 0.22). Example
284 responses include:

285 Pink I believe to be excellent for myself” (Participant 15), “Pink ball is very easy to see”
286 (Participant 6), and “White is still better to umpire” (Participant 14), “The white ball is
287 easier to see” (Participant 12).

288

289 Participants were asked if it would be better if cricketers wore coloured clothing whilst playing
290 in pink-ball matches. From the responses received (n=23), five participants responded yes
291 (22%), and 18 responded no (78%). The associated free text comments (n=10) identified the
292 following themes: coloured clothing would be harder (coverage 0.40). Responses included:

293 “Coloured clothing would make it harder. Coloured clothing and a coloured ball....no
294 thank you!” (Participant 9), “you get a good contrast between white and pink, other
295 colours might be harder to see ball” (Participant 14).

296

297 When asked if an alternative colour sight screen would aid visibility (as opposed to the white
298 screen currently used), 12 (46%) of the responding participants (n=26) answered yes, and 14
299 (54%) responded no. Participants elaborating on their answers highlighted the following
300 theme: black would aid visibility (coverage 0.71). Example responses included:

301 “Black is a clear background and easy to pick the ball out of” (Participant 28), “Black
302 screen, better contrast”, and “Black screens would aid visibility” (Participant 21).

303

304 The final question asked whether there were any playing grounds in which umpires found the
305 pink ball easier to see. Of the responding participants (n=19), five answered yes (26%), and
306 14 answered no (74%). Free text responses did not provide any meaningful themes.

307

308 **Section D – Further information**

309 The responses provided in this free text option (n=11) did not provide any additional
310 information to that supplied in sections A-C.

311

312 Responses throughout the survey for one participant who self-reported as having mild CVD
313 highlighted the difficulties that an umpire with a CVD may find with the visibility of the pink ball.
314 That umpire rated the visibility from the bowlers' end at dusk under floodlights as being worse
315 than the red ball under natural conditions (+5 reported), as when viewing the pink ball at night
316 under floodlights (+3 reported), at square leg at dusk under floodlights (+5 reported), and
317 square leg at night under floodlights (+3 reported).

318

319 **4. DISCUSSION**

320 Anecdotally, some cricket umpires have reported that they find it difficult to see the pink cricket
321 ball during dusk¹. This study sought to empirically investigate these reports using a cross-
322 sectional survey with a purposeful sample of elite cricket umpires. Findings fail to support the
323 anecdotal observations, with the visibility of the pink ball at dusk (and in the daytime) rated as
324 being no different to that of a red cricket ball during natural daylight. In fact, elite umpires
325 considered the visibility of the pink ball at night under lights to be significantly *better* than that
326 of the red ball during daylight hours. There are key differences between the red and pink balls
327 when considering them as visual stimuli. Unlike the red ball, the pink ball is fluorescent,
328 meaning the relative luminance, when viewed against a non-fluorescent background, will be
329 lowest when the exciting wavelengths are reduced. This would be particularly prevalent in
330 direct sunlight just before the onset of dusk.

331

332 In a recent study⁸, elite cricketers reported the visibility of the pink ball to be poorer at dusk,
333 under floodlights, both when batting and fielding, compared to the red ball in natural light.
334 Collectively, the results from the current study and previous work⁸ present contrasting views
335 on the visibility of the pink ball, raising interesting questions about the unique demands (visual
336 processing, enhanced concentration, adaptation) posed by the pink cricket ball on each of the
337 respective roles of umpires and cricketers. Research suggests the ventral and dorsal streams
338 are driven by retinocortical visual projection which is organised by at least three major
339 pathways (magnocellular – dorsal, parvocellular – ventral, and the koniocellular - dorsal). The
340 parvocellular cells manifest red-green opponency, the magnocellular cells are non-colour
341 opponent, while the koniocellular cells show yellow-blue opponency. The koniocellular
342 pathway appears likely to sustain some visual behaviours in the absence of either
343 magnocellular or parvocellular input. The ventral and dorsal pathways are responsible for
344 processing information pertaining to vision for action (dorsal), and vision for perception
345 (ventral)¹⁸. Therefore, the predictive element (pre-ball release information) requires

346 processing from the ventral stream, with the movement and action (post-ball release
347 interception) element processed by the dorsal stream. A batter will utilise both streams whilst
348 executing a shot or in the outfield, moving to intercept the ball. However, an umpire will
349 predominantly utilise the ventral stream for their predictive response. Findings from this study
350 add further support to research suggesting that information processed through the dorsal
351 stream is affected by the change or reduction in contrast luminance²³, thus accounting for the
352 differing opinions around the visibility of the pink ball.

353

354 An alternative explanation for the umpires not perceiving a difference in visibility between the
355 pink ball at dusk under floodlights and the red ball during regular daylight conditions may be
356 linked to the anecdotal report by ICC umpire Sunduram Ravi¹. Ravi stated that conditions with
357 (potentially) poorer visibility cause umpires to increase their levels of concentration. This
358 increased concentration may (subconsciously) nullify any visual difficulties experienced. It is
359 relevant to note that a study by Mann et al., (2007)¹³ found that low levels of induced blur did
360 not negatively affect cricket batting performance, with the authors suggesting that an increase
361 in concentration may be one of the factors mitigating against a decrement in performance.
362 Similarly, Wilkins & Appelbaum (2019)²⁴ proposed that one of the mechanisms of stroboscopic
363 visual training (a type of training where individuals perform actions under intermittent visual
364 conditions) may be that it leads to increased attention and effort. Thus, the idea that individuals
365 may mitigate impoverished visual conditions by increasing concentration could also be
366 applicable in the current study. This, however, does not explain why previous research⁸ has
367 shown cricket players to perceive the pink ball as having reduced visibility, particularly as they
368 would arguably have an even greater incentive to increase their concentration than the
369 umpires.

370

371 It is possible that the difference between current findings and the previous player-based
372 research⁸ could be due to the changes made by umpires in their positioning (coverage 0.20)
373 and equipment used (coverage 0.30), which provided comparable visibility to traditional
374 conditions as highlighted from the free text responses:

375 "I wear Oakley prism glasses" (Participant 15), "Standing back a bit further at dusk"
376 (Participant 8), and "I came closer at square leg to try and pick the ball up better from
377 side on" (Participant 17).

378

379 The use of sports eyewear to improve the visibility of the pink ball was discussed by Adie &
380 Arnold¹⁰. They suggest the use of rose-tinted lenses may help to counter the effects of any

381 change in luminance contrast when observing a pink ball at dusk under floodlights. In previous
382 research⁸, whilst some players commented on changes to their playing style, 92% reported
383 no changes in batting style and 91% reported no changes in fielding style in order to
384 accommodate for their perceived reduced visibility with the pink ball.

385

386 Although the results indicate that experience does not directly impact on the visibility of the
387 pink ball at either the bowler's end ($h=3.066$, $p=0.38$) or square leg ($h=3.58$, $p=0.31$) positions,
388 it is unclear if attending and participating in training sessions with a pink ball does. Within the
389 participant cohort, a section of umpires ($n=11$) reported attending and participating in training
390 (net) sessions. A subsidiary analysis on the effect participating in a training session had on
391 umpire's perceptions of the pink ball revealed that umpires who actively participated in training
392 reported a significantly higher rating of the visibility of the pink ball (mean -3.14 , $SD = 3.45$) at
393 night under floodlights compared to those who didn't (mean -0.67 , $SD = 3.39$: $u=181$, $p=0.010$).
394 Also, of interest is that the free text responses relating to changes in positioning made by
395 umpires came from umpires within the training-initiated group:

396 "At square leg, I will actively go to the other side if I think I will get a better contrast so
397 that I can track the ball better" (Participant 11), and "Apart from always standing on the
398 offside. When the ball is pulled on the leg side it is very difficult to see" (Participant 23).

399

400 From these results, it seems reasonable that umpires who attended training sessions
401 benefited from an increase in confidence in the visibility of the pink ball and offers the
402 opportunity to make potentially important adaptations to the elements of their on-field
403 application and/or concentration.

404

405 The pink ball may be particularly difficult for participants who are colour vision deficient
406 (CVD)²⁵, with some first-class players even withdrawing from pink-ball matches²⁶ because of
407 concerns about their own performance and safety⁶. One participant in this study self-
408 reported a CVD. When the responses of this participant were excluded, the results did not
409 change meaningfully and so their responses were included for all analyses. This participant
410 also passed the pre-season ECB visual screening assessment. These findings along with
411 reported perceptions of CVD cricketers^{6,8}, suggest the perceived visibility difficulties with the
412 pink ball may be exacerbated for CVD participants. Further research is required to explore
413 the effect on CVD cricketers, and how, if at all, the impact differs between different CVDs.

414

415 It is important to recognise the following limitations of the study. With the number and
416 frequency of day/night cricket matches using a pink ball being low, the exposure to matches
417 using a pink ball of the participants recruited is so-far relatively low. There is a possibility that
418 some of the responses given are due to inexperience or lack of exposure to the pink ball.
419 Additionally, the comparison between the pink ball under different lighting conditions with the
420 red ball under natural daylight conditions may have been difficult because the red ball is not
421 normally used during play under floodlights. Due to the geographical spread in both the
422 participants of the survey, and the locations in which pink ball Test cricket has been played, a
423 number of uncontrollable variables within the survey should be considered. The conditions in
424 which the day/night matches have been played may vary by country, overhead
425 conditions/weather, the time of year, and the make of the ball used. The aforementioned
426 uncontrollable variables may produce different responses from umpires officiating in different
427 countries/climates. This study provides an overview of the perceptions of pink ball visibility in
428 world cricket. Future research should consider introducing an experimental design to
429 mathematically model the visibility of both the pink and red balls under different lighting
430 conditions to empirically demonstrate whether there is any difference in the visibility between
431 the red and pink balls.

432

433 **5. CONCLUSION**

434 Elite cricket umpires reported no difference in the visibility of the pink ball and the red ball
435 when umpiring from both the bowler's end and square leg positions under natural light and at
436 dusk under floodlights. The pink ball was reported to be *more* visible at night than the red ball
437 under regular daylight conditions when umpiring from both the bowler's end and square leg,
438 with a significant increase in visibility compared to dusk when positioned at square leg. These
439 findings differ from previous research with elite cricketers⁸ on the same topic who reported
440 difficulties with the visibility of the pink ball particularly at dusk. The key distinction in the task
441 of umpires and batters/fielders is whether they need to intercept the ball or not. A batter must
442 act to intercept the ball (vision-for-action) in order to preserve their wicket (not be given out)
443 and to accumulate/score runs. The key task for the umpire is to complete the complex series
444 of (visual) tasks to make decisions, including predictive decisions about where the trajectory
445 of the ball would have continued if the interception had not taken place (vision-for-
446 perception)¹⁸. The looming sign for the umpire is opposite to that faced by the batter and close
447 fielders (directly behind the batter)²⁰. With that in mind, it is suggested that the contrasting

448 perspectives of umpires and players with regards the visibility of the pink ball may be due to
449 the differences in the information processing required.

450

PRACTICAL IMPLICATIONS

- 451 • This systematic investigation of elite cricket umpires' opinions suggests that the visibility of
452 the pink cricket ball is equal to or better than the red ball in traditional conditions.
- 453 • The results of this study suggest that the visibility of the pink ball is significantly better at
454 night under floodlights from both bowler's end and square-leg positions, and significantly better
455 at night than at dusk from the square-leg position.
- 456 • The results indicate that the pink ball is suitable for day/night Test matches from an umpire
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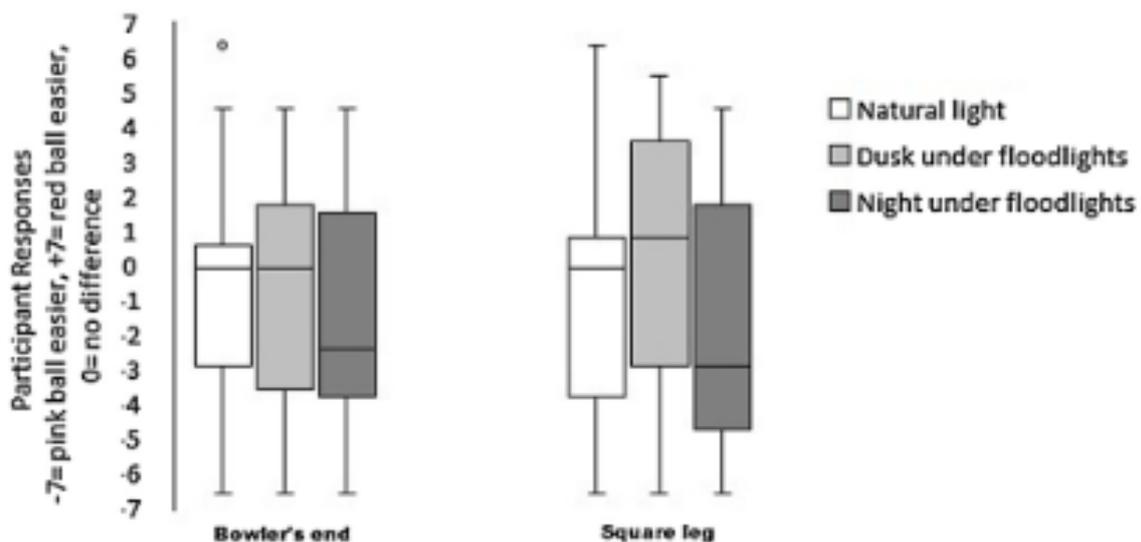
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538

539 **Figure 1**

540



541

542 Figure 1. Participant ratings of visibility of the pink ball, when compared to the red ball in
 543 natural daylight, in three different light conditions officiating from (A) the bowler's end and (B)
 544 square leg positions. The solid line within each boxplot represents the median response and
 545 the circle represents an outlier.

546

547

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INSERT APPENDIX A1 ABOUT HERE

550