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Increasing conspicuity on night-time roads: perspectives from cyclists and runners

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1 **Abstract**

2 Pedestrians and cyclists are at significant risk of being killed as a result of a collision with a
3 vehicle at night-time because of their poor conspicuity. Retroreflective strips positioned on
4 the moveable joints, in a biological motion configuration (biomotion), greatly enhances the
5 night-time conspicuity of pedestrians and cyclists, but it is not clear how widely this strategy
6 is adopted among those running and cycling under low light levels and at night. This study
7 explored runners' and cyclists' beliefs about their own conspicuity, and the strategies they
8 use to increase their conspicuity and safety under low light levels

9

10 Nine focus groups involving 50 participants (mean age =39.5 ± 13.9 years) were held with
11 individuals who ran and/or cycled under low light conditions or at night-time. Participants
12 explored the strategies they used to increase their perceived conspicuity and enhance their
13 personal safety, and the importance they placed on increased visibility to other road users at
14 night. Data were analysed thematically, with two main themes identified. *Strategies* describes
15 the different approaches used to increase their own conspicuity when running or cycling in
16 low light conditions, which include ineffective strategies. *Importance* describes how
17 conspicuity relates to other considerations that influence cyclists and runners. While they
18 may believe that conspicuity is essential for their safety, they may compromise their own
19 conspicuity by prioritising style or comfort, or because they believe that being more
20 conspicuous is of limited value because it cannot compensate for the behaviour of other road
21 users.

22

23 In summary, cyclists and pedestrians are largely unaware of effective strategies to increase
24 their night-time conspicuity, particularly the use of biomotion reflective strips. Garment
25 manufacturers should ensure that conspicuity features (with supporting educative product
26 information on labels) are incorporated into cyclists' and runners' clothing or accessories, to
27 improve wearer conspicuity and hence safety in low light conditions.

28

29 **Keywords:** night-time visibility, conspicuity, cyclists, runners, biomotion, clothing

30 **1. Introduction**

31 Pedestrians and cyclists are at significant risk of being injured or killed as a result of a
32 collision with a vehicle at night time (Kwan and Mapstone 2004), because of their poor
33 conspicuity (Owens and Sivak 1996). Crashes between vehicles and pedestrians are over-
34 represented at night, with pedestrians being 3-7 times more likely to be involved in a fatal
35 collision at night than in the day (Sullivan and Flannagan 2002). Even though exposure rates
36 for cycling are much lower at night than in the day, data from a range of countries indicate
37 that cyclist fatality rates at night are high (Jaermark, Gregersen et al. 1991; Henley and
38 Harrison 2009). The risk of injuries at night is also two times higher at night than in the day,
39 and for rural areas the injury risk is five times higher (Johansson, Wanvik et al. 2009; Twisk
40 and Reurings 2013).

41

42 During the daytime, fluorescent materials are effective in increasing conspicuity (Kwan and
43 Mapstone, 2009) and can reduce collisions (Lahrmann et al., 2018), while at night, lights and
44 retroreflective materials are more effective (Kwan and Mapstone, 2009). Retroreflective
45 material can enhance the nighttime conspicuity of cyclist, walkers and runners and there has
46 been some debate regarding where this retroreflective material should be placed in order to
47 achieve optimal conspicuity. When retroreflective materials are positioned on the major
48 movable joints, this creates a sense of “biological motion” or “biomotion”, i.e. the viewer
49 perceives the lights as moving body parts on a person or animal (Johansson 1975; Tyrrell,
50 Wood et al. 2016). The visual system is extremely sensitive to biological motion and this
51 ability allows information, such as whether a moving person is present and the characteristics
52 of their movements, to be extracted from the motion of tiny point lights located on the major
53 joints (Johansson 1975). When retroreflective strips are placed on the movable joints and are
54 lit up in the oncoming headlight beam they produce a sense of biological motion that
55 enhances drivers’ ability to recognise pedestrians from a safe distance at nighttime, resulting
56 in a 20 times increase in the distance at which a pedestrian or cyclist is first recognised
57 (Wood, Tyrrell et al. 2005).

58

59 This research on the benefits of biological motion has resulted in a change to the Australian
60 and New Zealand standard for high-visibility clothing for night-time road workers (King and
61 Wood 2013), yet there has been no translation to other groups that use road systems at night.
62 This is despite there being a large number of people who walk, run or cycle on our roads at
63 night-time, either for commuting or exercise. There are likely to be many more individuals

64 who do not undertake these activities because of concerns regarding their safety (Daley,
65 Rissel et al. 2007). Indeed, concerns about conspicuity mean that parents drive their children
66 to school rather than allow them to cycle (Ghekiere, Van Cauwenberg et al. 2014), with
67 parental constraints on physical activity extending beyond active transport to reducing the
68 amount of physical activity that children undertake outside of school (Carver, Timperio et al.
69 2010). This is of particular concern given the link between low levels of physical activity,
70 obesity and consequent morbidities. A recent meta-analysis demonstrated that active
71 commuting such as walking, running or cycling can be associated with an 11% decrease in
72 risk of cardiovascular disease (Hamer and Chida 2008); other implications include reductions
73 in traffic congestion and vehicle emissions.

74

75 Studies have also shown that there is a lack of clarity among vulnerable road users regarding
76 the conspicuity effects of different materials, such as florescent and retroreflective materials
77 (Wood, Tyrrell et al. 2013). Fluorescent materials convert invisible ultraviolet light in natural
78 daylight to visible light (Joint Technical Committee 1999) and so increase conspicuity only
79 under daytime conditions, whereas retroreflective materials reflect light such as headlights
80 back towards the light source so are more effective in low light conditions (Wood et al.,
81 2013). People are also often resistant to wearing clothing that has a safety focus because it
82 lacks aesthetic appeal or is perceived to be cumbersome or uncomfortable. Clear examples of
83 these concerns about style and comfort are reluctance to wear cycle helmets because of a
84 belief that they are unattractive (Lajunen 2016), or because they are uncomfortable
85 (Hollenberg 2018). Similar considerations are likely to affect willingness to wear other
86 clothing and accessories. In addition, research has demonstrated that despite cyclists being
87 generally well informed regarding the importance of wearing high-visibility clothing and the
88 benefits of conspicuity aids, they frequently do not use these aids (Hagel, Lamy et al. 2007).

89

90 This study aimed to better understand the strategies that cyclists and runners use to increase
91 their conspicuity and safety at nighttime and the relative importance that they place on
92 increased conspicuity to other road users at night, both in terms of perceptions, and their
93 choices of exercise clothing and associated apparel accessories at night.

94

95

96

97

98 **2. Methodology**

99 A primarily qualitative methodology was employed, comprising a series of focus groups
100 conducted in three countries. Participants were also asked to complete quantitative rating
101 scales.

102

103 *2.1 Participants*

104 In total there were 50 participants (mean age =39.5 ± 14.0 years, 20 female, 30 male); 34
105 from Brisbane (Australia) and 16 from Leeds (United Kingdom). These cities provide
106 locations that differ in respect to their climate and the extent to which residents cycle for
107 commuting and leisure purposes. Participants were adults who ran/cycled on the roads in low
108 light conditions, lived or worked locally in each city and were recruited through
109 advertisements through workplaces, social media groups and through emails to cycling and
110 running groups. Potential participants completed an online recruitment form and were booked
111 to attend a focus group based on their activity type (night-time cyclists or runners or those
112 who undertook both cycling and running at night (mixed)). Three groups were with those
113 who solely or mostly cycled, three with those who solely or mostly ran, and three with those
114 who both cycled and ran. All participants were offered an AU\$50 gift voucher for their
115 participation in the focus group.

116

117 *2.2 Procedure*

118 Nine focus groups were held: six in Brisbane, Australia (two cyclists, two runners, two
119 mixed) and three in Leeds, UK (one cyclist, one runners, one mixed). Focus groups provide a
120 means of gaining an in-depth understanding of a topic or issue in a group setting, where the
121 dynamics of the group lead to participants disclosing and discussing their thoughts, feelings
122 and experiences in a way that they may not do in a one-to-one interview. A semi-structured
123 topic guide was used to initiate and steer the discussion. The term “visibility” was used
124 throughout rather than “conspicuity” as it is easier for participants to understand. Discussions
125 covered:

126

- 127 • Clothing worn when running/cycling under nighttime conditions;
- 128 • Choosing clothing for running/cycling;
- 129 • Perceptions of participants’ own visibility to motorists at nighttime.

130

131 At the Brisbane site, participants in each group were asked to rate the relative importance of
132 visibility versus comfort, and visibility versus style when purchasing clothing, by placing a
133 mark on two separate visual analogue scales (VAS) of 250 mm in length. The first VAS
134 contrasted the importance of visibility versus comfort with three anchor points: visibility as
135 being of sole importance; visibility and comfort being of equal importance; and comfort
136 being of sole importance. The second scale contrasted the importance of visibility versus
137 style, scaled from visibility as being of sole importance; visibility and style being of equal
138 importance; and style being of sole importance. Participants' positions along the VAS were
139 converted to numbers by applying a conversion factor (scale position – 125) x 0.08, such that
140 the anchor points indicating equal importance were set at 0.

141

142 Focus groups were led by one of two facilitators (FF, LB), who were either highly
143 experienced in conducting focus groups (FF) or had undergone extensive training in
144 delivering focus groups (LB) and were aided by an assistant, lasted one hour and were audio
145 recorded and transcribed verbatim. The study followed the tenet of the Declaration of
146 Helsinki and ethics committee approval was obtained from Queensland University of
147 Technology. All participants were given a full explanation of the nature of the study, what
148 taking part would involve, and how to withdraw from the research. Written informed consent
149 was obtained.

150

151 *2.3 Data analysis*

152 Transcripts were analysed thematically using the methods of Braun and Clarke (2006).
153 Transcripts were coded using the research question: “What does conspicuity mean to
154 runners/cyclists?” and referred to the key points covered in the topic guide. An inductive
155 approach was taken in which the codes were generated from the data rather than by applying
156 a pre-determined framework (Braun and Clarke (2019). Two authors (FF, LB) independently
157 coded the transcripts and any differences in coding were discussed and resolved. Codes were
158 grouped together with others of similar meaning and sorted into a thematic structure that best
159 described the data. The criteria for a theme were that it was internally homogeneous, i.e. the
160 sub-themes it contained all shared a certain perspective, and that it was externally
161 heterogeneous, i.e. that the themes were fundamentally different from one another. This stage
162 was iterative, with sub-themes merging and moving between themes until a grouping was
163 identified that provided the most parsimonious data structure while capturing the full set of
164 codes.

165 **3. Results**

166 *3.1 Qualitative Results*

167 Two main themes were identified in the data:

- 168 • **Strategies** describes the different approaches that people use to try to increase their
169 own conspicuity when running or cycling in low light conditions;
- 170 • **Importance** describes how conspicuity relates to other considerations that
171 influence cyclists and runners: while they may believe conspicuity to be essential
172 for their safety, they may compromise their conspicuity by prioritising style or
173 comfort, or because they believe that being more visible is of limited value because
174 it cannot compensate sufficiently for the behaviour of other road users.

175

176 These themes are described in detail below and illustrated using quotes from each of the
177 focus groups that were selected on the basis that they best illustrated each sub-theme, and
178 were labelled with the city that the focus group took place (Brisbane or Leeds), the focus
179 group number and the gender of the participant.

180

181 **1. Strategies**

182 This theme comprises four subthemes that describe what participants do to increase their
183 conspicuity when cycling or running, and how that changes under low light conditions, i.e. at
184 dawn, dusk or at nighttime.

185

186 ***Lights***

187 This sub-theme describes beliefs and experiences regarding using lights to increase
188 conspicuity at night. Cyclists in particular, relied heavily on lights, with many using lights
189 during the daytime as well as under low light conditions. They believed that lights, high
190 lumen LEDs in particular, are the most effective strategy to increase their own conspicuity,
191 and accordingly, many were willing to pay more for higher lumen LED lights because they
192 are brighter. Many participants described using multiple lights, e.g. on the front and rear of
193 their bikes and also on their helmets, as more lights were considered to be superior for
194 gaining motorists' attention.

195

196 *“I have a 600 lumen light on my handle bars, a 200 lumen tail light and a 300 lumen*
197 *light on my helmet. If I'm really bright everyone is seeing me from ages away.” (FG*
198 *Brisbane 5, male)*

199
200 *“I have five lights on the back of my bike that I commute on: some flash, some are static.*
201 *I am literally glowing head to toe.” (FG Leeds 3, male)*

202
203 Some participants (from both Brisbane and Leeds) noted that it is illegal to ride at night
204 without lights, and this increased the perception that lights are the best way to increase
205 conspicuity in low light and darkness. Discussion focused on the relative efficacy of flashing
206 versus constant lights. Some believed that flashing lights decreased conspicuity and others
207 that flashing would attract drivers' attention. Several participants had lights on their helmets
208 and believed that this is useful to increase their conspicuity at a junction where they would
209 look around and at cars as a strategy to increase conspicuity.

210
211 Very few participants used lights while running, although most were aware of them and
212 several talked about how clip-on LED lights can be a useful way of increasing conspicuity
213 when running on or near a road. A few talked about using head torches, although this was
214 primarily to increase what they can see, rather increase their own conspicuity to other road
215 users.

216
217 ***Colour***

218 Many participants, including both cyclists and runners, used colour as a strategy to increase
219 their conspicuity and talked about brightly coloured clothing as being very effective at night.
220 Cyclists also talked about the colour of their bike and cycle helmet increasing their
221 conspicuity. While there was discussion around how bright colours are most effective in
222 daylight, some participants had strong beliefs that bright colours would increase conspicuity
223 even in low light and darkness. Light colours were highlighted as being more effective in low
224 light conditions and several participants talked about how they would try to avoid wearing all
225 black in low light.

226
227 *“I go for bright colours normally because I run home on the roads and people are a*
228 *bit crazy so I like to be seen especially in the dark.” (FG Brisbane 4, male)*

229

230 *“I have a bright orange bike so if they can't see the bike then they're not going to see*
231 *me.” (FG Leeds 1, male)*

232

233 A few discussed how colour contrast is very important, so bright green would be a good way
234 of increasing conspicuity in a city but not in a rural area with lots of vegetation. There was
235 confusion between bright colours and fluorescent colours. Participants believed that
236 fluorescent clothing is more visible at night but were often not sure whether a clothing item
237 was fluorescent or simply bright.

238

239 ***Retroreflective material***

240 Some participants talked about wearing retroreflective clothing in low light but many had not
241 previously considered this as an effective means of increasing conspicuity. Some suggested
242 that this was because it can be difficult to tell whether a garment is retroreflective.

243 Participants talked about how manufacturers or retailers often don't mention retroreflectivity
244 on garments, which suggests it is not important. Indeed, many talked about how they forget
245 or don't think to check about retroreflectivity when they are buying cycling or running
246 clothing, so that buying clothes with retroreflective material is not a deliberate decision.

247

248 *“I've bought stuff online and not realised until I got it that it had retroreflective stuff*
249 *on it.” (FG Brisbane 5, female)*

250

251 Some participants discussed how their running and cycling shoes have retroreflective
252 material on the heels but few had considered the conspicuity benefits. Some talked about
253 retroreflective strips on shoes and clothes being too small to be seen at distance and so
254 therefore not an effective way of increasing conspicuity. There was discussion regarding how
255 some brands have retroreflective detailing on a garment's seams or on a logo and how this
256 suggests that retroreflective strips are a design feature rather than a safety feature. Some were
257 aware of jackets and rucksacks made entirely out of retroreflective material and most firmly
258 believed that increasing the amount of retroreflective material in a garment would increase its
259 conspicuity. Alongside this, some participants were aware of apparel accessories such as
260 socks, gloves and arm bands with retroreflective trimming but wore these items primarily for
261 protection from the weather. Only three participants suggested that retroreflective materials
262 “that move with you”, such as ankle bands, are effective. No other participants were aware of

263 biomotion. Most considered retroreflective strips in clothing as “nice to have” rather than
264 essential.

265

266 *“The shorts that I have actually have a reflective strip on the back; it's something that*
267 *just came with them. I didn't think about it when I bought them but I guess it is*
268 *probably good because I run on the roads a lot.” (FG Brisbane 3, female)*

269

270 **Route choice**

271 Participants talked about how they usually choose routes that are brightly lit as a strategy to
272 increase their conspicuity. For runners, however, this often means that they run alongside
273 main roads and so encounter more traffic. They believed this to be safer than running on quiet
274 roads, which might put their personal safety at risk. Some talked about choosing routes with
275 low levels of traffic when they know their conspicuity is low.

276

277 *“As a lady I wouldn't be running while it's dark at night on my own so I'm always*
278 *running by the side of the road [under street lights].” (FG Leeds 1, female)*

279

280 *“If I go for a ride at night I will try and like, I know I'm wearing dark clothes so like*
281 *I'll try and use routes that aren't heavily trafficked.” (FG Brisbane 1, male)*

282

283 **2. Importance**

284 This theme describes participants’ perceptions of the importance of trying to increase their
285 conspicuity in relation to other considerations. While they believed that conspicuity would
286 increase their safety on the roads, there are tensions, with other considerations that may mean
287 that conspicuity is considered as relatively less important, or that the behaviour of other road
288 users means that it is not as effective as it might be.

289

290 **Safety**

291 This sub-theme is about how being visible to other road users is essential to stay safe on the
292 roads. While all participants talked about the importance of conspicuity, those who had been
293 involved in a collision, either as a runner or a cyclist, were particularly keen to be
294 conspicuous. Cyclists believed conspicuity to be more important than did runners, although
295 the context of their ride influenced perceptions of the importance of conspicuity, with
296 conspicuity being described as less important when riding in a group. Indeed, participants

297 talked about the importance of wearing “club kit” on a group ride, which is rarely designed
298 for conspicuity.

299

300 *“I’ve got dark cycling gear and I’ll wear that if I’m in a big group but if I’m by myself*
301 *I will pick out brighter colours.” (FG Brisbane 5, male)*

302

303 In contrast, conspicuity during a commute ride was perceived as being especially important:
304 participants talked about how drivers are less likely to notice a single cyclist, and commuting
305 drivers may be tired or distracted so less likely to actively look out for cyclists.

306

307 *“Commuting seems to be a more dangerous time because people are rushing about*
308 *trying to get to work in the car. It generally busier and you know people aren’t always*
309 *taking as much time or driving as well as they might do.” (FG Leeds 1, female)*

310

311 Runners talked less about conspicuity being important, with many noting that most collisions
312 happen when runners cross the road without looking. However, more concerns about
313 conspicuity were raised by those who run on the road on routes without sidewalks (paved
314 paths for pedestrians at the side of the road). Parents who run or ride with their children were
315 more concerned about their children’s conspicuity than they were about their own.

316

317 *“I just think he [my 10-year-old] needs to be so visible when we run just in case he*
318 *misses something or someone is flying around the corner. Because sometimes he will*
319 *just step out and look this way but then someone could just, you know what I mean. I*
320 *just think it’s definitely really important to be really really visible.” (FG Leeds 2,*
321 *male)*

322

323 ***Tensions***

324 This sub-theme describes factors that reduce the perceived importance of conspicuity. The
325 main issue discussed by cyclists was the attitudes and behaviours of drivers. Many cyclists
326 described drivers failing to notice them, often despite looking directly at them. All cyclists
327 talked about experiencing close passes, and many believed that drivers sometimes do this
328 deliberately.

329

330 *“I’ve had so many experiences where I’ve had drivers looking directly at me and I’ve got*
331 *bright flashing lights on the front and they still don’t see me.” (FG Brisbane 2, female)*

332

333 *“Never trust a motorist because they’re not looking out for you. All they want to do is get*
334 *home after the end of their commute or whatever. They will purposefully cut cyclists up.*
335 *There are people who will literally park in the gutter to try to stop you from going up the*
336 *inside because you’ll gain a metre.” (FG Leeds 3, male)*

337

338 There was considerable discussion about how driver behaviour sometimes makes it feel that
339 it is pointless for cyclists to try to increase conspicuity. Some participants talked about how
340 they do not agree that the emphasis should be on cyclists or runners making themselves more
341 visible. Instead, it should be up to drivers to actively look for other road users and for
342 authorities to design safer junctions and install more bike paths.

343

344 *“I think are think there are two possibilities, one is the personal possibility for high visibility*
345 *I think on the other side there is the responsibility from the government that they are*
346 *responsible for good visibility, for good lit junctions and especially the point where we have*
347 *accidents.” (FG Brisbane 6, male)*

348

349 There were several discussions about that drivers tend to be more considerate around cyclists
350 who look less experienced or less safety conscious, so that wearing high visibility clothing
351 that looks more professional could paradoxically put them at greater risk.

352

353 *“The more you look like a daggy commuter I think the more cars will avoid*
354 *you.” (FG Brisbane 2, male)*

355

356 *“I don’t want to look like a cyclist. I want to look like a tradesman who’s going*
357 *somewhere.” (FG Brisbane 6, male)*

358

359 Some of the runners talked about how cyclists on shared paths represent a significant hazard,
360 and how cyclists often have little regard for runners. In the Brisbane groups, electric scooters
361 were also identified as a hazard.

362

363 “Cyclists can be a bit more aggressive on shared paths because they're the bigger
364 thing. They'll yell at you to get out of the way and I'm literally like: I've got nowhere
365 to go, so you can literally slow down a bit, wait for a point to go around me.” (FG
366 Brisbane 3, female)

367

368 “The amount of scooters where I've yelled at people, nearly got taken out and watch
369 them nearly take out me.” (Brisbane, 3, Female)

370

371 ***Practicality and Style***

372 Another tension, discussed by both cyclists and runners, was that comfort and durability are
373 more important than conspicuity when buying clothing. Participants discussed how clothing
374 should be appropriately warm or cool, sweat wicking, with a good fit and style. Black was
375 thought to be a practical colour as it does not show dirt or sweat. There were concerns that
376 retroreflective strips would cause chaffing, compromise the fit, would make them overheat,
377 would require the garment to have long sleeves or pants, or mean that the garment can't be
378 washed as often. All of these disadvantages were perceived as being more important than a
379 potential increase in conspicuity.

380

381 “*When you're buying you don't really think of visibility. It's more the look and the*
382 *comfort of it.*” (FG Brisbane 4, male)

383

384 Cost was also a consideration, where few participants would be prepared to pay significantly
385 more for clothing that increases their conspicuity. Some participants did not have specific
386 clothes for cycling and wear the clothes they will be working or socialising in, which are not
387 optimised for conspicuity, thus any safety elements would need to be subtle.

388

389 “*I wouldn't pay more for reflective but I do think it's a good idea.* (FG Brisbane 4)

390

391 “*If I thought about it was that it might cost you \$40 more for a jersey, it's not a lot to*
392 *pay to potentially reduce the chance of getting hit.*” (FG Brisbane 2, male)

393

394 ***Personal Safety***

395 Some runners, particularly female, talked about how they prefer *not* to be visible when they
396 are wearing running clothing. For some, this is because they are embarrassed about their

397 appearance and they would rather not attract attention to themselves. Others, were concerned
398 that they would be a target for crime when running alone.

399

400 *“I run in busy areas, so well lit like main roads. I don't run on back roads in the dark*
401 *so during the day I'll do like suburbs but like at night I'll do main roads.” (FG*
402 *Brisbane 4, female)*

403

404 *“I'd prefer to be low visibility in that I'm not noticeable because I'm slow and I do*
405 *like listening to music when I run so I think that's also a safety thing. So I think*
406 *actually I'm all in black no one is going to see me.”(FG Brisbane, 1, female)*

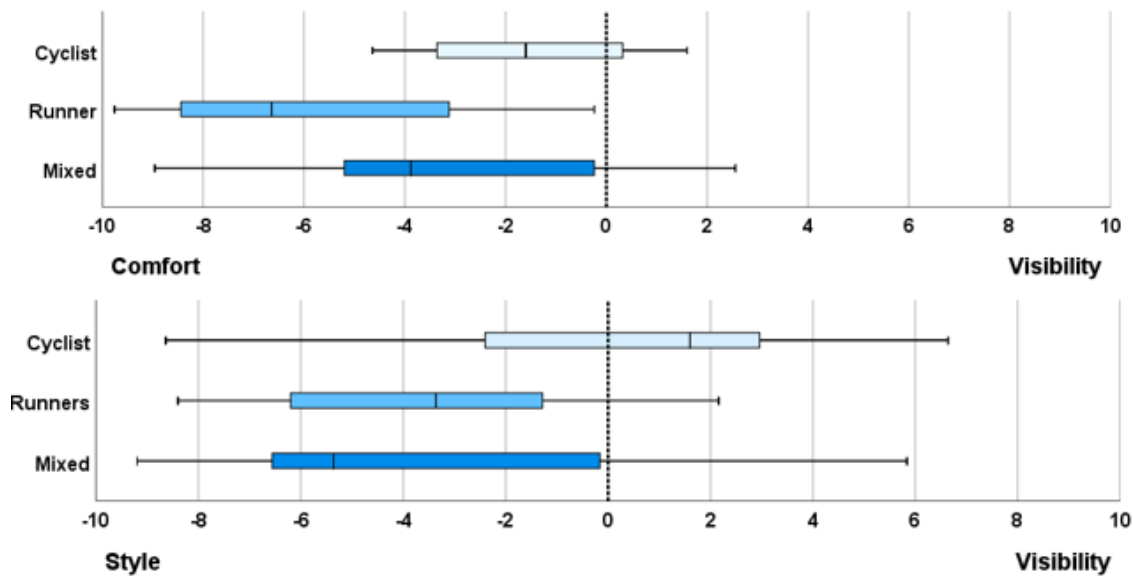
407

408

409 *3.2 Quantitative Results*

410 Our small group of participants rated both comfort ($M = -3.47, SD = 3.51$) and style ($M = -$
411 $2.03, SD = 4.52$) as relatively more important than visibility. A one-way between subjects
412 ANOVA was conducted to compare the effect of group membership (cyclist, runner or
413 mixed) on the importance of visibility when compared with comfort and style. There was a
414 significant effect of group membership for the comfort vs. visibility ratings ($F(2,32) = 5.88, p$
415 $= .007$) (Figure 1). Post hoc comparisons using the Tukey HSD test revealed no significant
416 differences between the mixed groups ($M = -3.16, SD = 3.89$) and the runners and cyclists
417 groups. However, the mean score for runners ($M = -5.79, SD = 3.26$) was significantly lower
418 than cyclists ($M = -1.58, SD = 2.10$); $p = .005$. While all groups were more concerned about
419 comfort, runners are more concerned about comfort and less concerned about style than
420 cyclists.

421



423

424 **Figure 1.** Boxplots of participants' ranking of the importance of visibility compared to
 425 comfort and style, when purchasing sports clothing for the Cyclists, Runners and Mixed (both
 426 a runner and cyclist) groups.

427

428 There was also a significant effect of group membership for visibility vs. style ($F(42,32) =$
 429 $4.19, p = .024$) (Figure 1). Post hoc comparisons revealed no significant differences between
 430 the mixed groups ($M = -3.51, SD = 4.83$) and the runners and cyclists groups. However, the
 431 mean score for runners ($M = -3.67, SD = 3.18$) was significantly lower than for cyclists ($M =$
 432 $0.60, SD = 4.36$); $p = .039$, indicating that cyclists rate visibility as more important than style
 433 relative to the runners.

434

435 **4. Discussion**

436 We explored perceptions of conspicuity under low light conditions for cyclists and runners.
 437 Two main themes were identified in the focus groups: Strategies and Importance. The first
 438 theme, *Strategies*, describes what cyclists and runners do to increase their conspicuity under
 439 low light conditions i.e. dawn, dusk or nighttime. This theme incorporated four subthemes of
 440 Lights, Colour, Retroreflective Material and Route Choice. The second theme, *Importance*,
 441 revealed participant's perceptions of the importance of trying to increase their conspicuity in
 442 relation to other considerations. This theme also incorporated four subthemes of Safety,
 443 Tensions, Practicality and Style and Personal Safety.

444 Overall, the results demonstrate that there was a belief that lights are the most effective way
445 to increase conspicuity, with cyclists relying heavily on bicycle lights in order to be seen.
446 There was considerable discussion about the relative efficacy of flashing versus constant or
447 static bicycle lights. Some participants believed that flashing lights decreased conspicuity,
448 whereas others thought that flashing increased conspicuity through attracting drivers'
449 attention. Survey-based research indicates that bicycle lights are rated as being more visible
450 to drivers by participants who are cyclists, than by participants who are drivers themselves,
451 particularly at night (Wood, Lacherez et al. 2009). Indeed, a bicycle light, whether static *or*
452 flashing, did not improve drivers' ability to recognise that a cyclist was present on the road
453 ahead in studies undertaken on a closed road circuit (that is free of other traffic) at night-time
454 (Wood, Tyrrell et al. 2012). There was also no discussion in the focus groups of the fact that
455 lights provide drivers with only limited distance cues, so they cannot identify how far away a
456 cyclist or runner is. Indeed, research has demonstrated that a tri-light formation can provide
457 cues regarding approach speeds under low light conditions (Gould et al., 2012). Thus while
458 bicycle lights may alert drivers that there is something on the road ahead, it does not allow
459 them to recognise that it is a cyclist or runner, nor their distance away.

460

461 Many participants discussed how they relied on colour to increase their conspicuity at night
462 and believed that brightly coloured clothing and fluorescent clothing is effective, even under
463 low light conditions. This finding is consistent with previous survey results (Wood, Lacherez
464 et al. 2009), and quantitative research on a driving circuit (Wood, Tyrrell et al. 2013), that
465 also found that cyclists overestimate the effectiveness of fluorescent clothing at night.

466 Additionally, participants favoured having colour on their bike or helmet to increase
467 conspicuity. It has been suggested that one potential reason for this preference might be the
468 Helmholtz-Kohlraush effect, where intense saturation of the spectral hue is perceived as part
469 of the colour's luminance, hence people believe that bright colours will increase conspicuity.
470 However, research has demonstrated that the Helmholtz effect diminishes when ambient
471 illumination is low (Ikeda and Ashizawa 1991; Stalmeier and de Weert 1994; Sayer, Mefford
472 et al. 1998; Sayer, Mefford et al. 1999).

473

474 One of the most important elements identified from the focus groups was that few
475 participants acknowledged the importance of retroreflective clothing in low light conditions.
476 The majority had not considered retroreflective material as being an effective means of
477 increasing conspicuity. Furthermore, there was a clear consensus among participants that a

478 larger surface area of retroreflective material increases conspicuity and there was discussion
479 of the benefits of jackets and rucksacks made entirely out of retroreflective material. This
480 finding is consistent with previous research which identified that cyclists rated wearing a
481 retroreflective vest as being more effective for increasing conspicuity over and above the use
482 of retroreflective strips worn on the moveable joints (Wood, Lacherez et al. 2009). However,
483 retroreflective vests have been demonstrated to be significantly less effective for increasing
484 conspicuity, as a high concentration of retroreflective material is limited to the torso,
485 subsequently delivering less motion information to approaching motorists (Wood, Tyrrell et
486 al. 2013). In contrast, wearing retroreflective strips on the moveable joints creates the effect
487 of biomotion, where a driver can actually recognise that a human is present, rather than
488 misinterpreting the illuminance for a sign or a boulder. In one closed road study conducted
489 under low-beam headlight conditions, drivers recognised the presence of a pedestrian at a
490 distance that was more than 20 times further away when the pedestrians wore clothing
491 incorporating retroreflective material in a biomotion configuration, as compared to wearing
492 black clothing (148 m vs 6 m respectively) (Wood, Tyrrell et al. 2005).

493

494 Other interesting findings included that the selection of more brightly lit running routes in
495 order to try and increase their conspicuity for a few participants. However, this often meant
496 that they run alongside main roads, which exposes them to more traffic.

497

498 All participants talked about the importance of conspicuity, however, those who had been
499 involved in a collision, either as a runner or cyclist, were more motivated to be conspicuous.
500 While these perceptions of the importance of conspicuity are encouraging, individuals should
501 not have to experience a potentially fatal crash in order to recognise these concepts.
502 Moreover, cyclists believed that conspicuity whilst commuting is essential, as drivers may be
503 tired or distracted and less likely to actively look out for other road users. However, a number
504 of cyclists noted that when riding in a group, the emphasis on the importance of conspicuity
505 decreases. This finding supports previous research that investigated the differences in safety
506 perceptions between cyclists and drivers. Indeed, research has indicated that cyclists rate
507 riding in a pack to be significantly safer than drivers' perceptions of cyclists safety when
508 riding in a pack (King, Wood et al. 2012). These authors concluded that one's self-
509 identification as a cyclist is associated with interpreting one's cycling behaviour as being
510 safer than drivers consider it to be. This can be linked to the idea of a 'pack mentality' and
511 the misperception of 'safety in numbers' when cyclists ride in groups. When riding in a

512 group, cyclists may become less aware of their surroundings and less concerned for safety
513 compared to when cycling alone, where they are solely responsible for looking out for
514 motorists. This can be linked to the social psychology phenomenon of Social Loafing, where
515 there is a tendency for individuals to expend less effort when working collectively compared
516 to when working individually (Karau and Williams 1993).

517

518 Additionally, runners commented that the majority of collisions occur when runners cross the
519 road without looking. Therefore, runners who had to interact with roads or motorists at some
520 point in their run were more concerned about conspicuity than runners who solely run on off-
521 road paths. In terms of research evidence, there are no available statistics regarding the
522 number of pedestrian casualties that occur while undertaking exercise such as running at the
523 time of their collision with a vehicle. However, there are numerous anecdotal accounts in the
524 media regarding the number of runners killed or injured at night-time and the fact that that
525 these incidents commonly occur when runners are crossing the road.

526

527 Numerous discussions explored the tensions between cyclists and drivers, with cyclists noting
528 that drivers often fail to notice them, even when directly looking at them. This phenomenon
529 has been termed “looked-but-failed-to-see” (Herslund and Jorgensen 2003), where drivers
530 fail to detect a cyclist in time to prevent the crash, even though they report that they had
531 correctly looked in the direction of the cyclist. This late (or non) detection of cyclists
532 highlights that lack of conspicuity may be a critical contributing factor to their crash
533 involvement (Lacherez, Wood et al. 2013), however, it also confirms cyclists’ beliefs that
534 regardless of what they wear, drivers may fail to see them. Indeed, many of the cyclists that
535 participated in the focus groups believed that drivers deliberately pass close to cyclists to
536 unnerve them and this antisocial behaviour leads cyclists to believe that increasing
537 conspicuity is pointless. Interestingly, some cyclists believed that motorists give more room
538 to cyclists who look more ‘inexperienced’ when overtaking than those who dress in sports
539 clothing, although there is evidence that this does not occur in practice (Walker, Garrard et al.
540 2014; Debnath, Haworth et al. 2018). Furthermore, many participants suggested that
541 emphasis should not be placed on cyclists and runners to make themselves more visible, but
542 that drivers should actively look out for other road users and government authorities should
543 design safer junctions and increase the amount of bike paths.

544

545 It was clear across all groups, that the practicalities of the garment outweigh the importance
546 of conspicuity. The consensus was that it does not matter how visible the garment is: if it is
547 not comfortable, no one will wear it. Conspicuity was almost unanimously considered to be
548 an added benefit rather than a core criterion when choosing exercise clothing. A quantitative
549 approach allowed us to identify which group of road users (runners, cyclists or mixed) are
550 more likely to prefer clothing that offers comfort or style over visibility. While these results
551 are based only on a small sample they demonstrate that both cyclists and runners believe
552 comfort to be more important than visibility. Runners also rated style as more important than
553 visibility. Overall, cyclists rated visibility as slightly more important than style, although
554 there was a wide variation in responses. This is perhaps because cyclists, by nature of
555 spending more time on roads and in traffic than runners, have more exposure to drivers and
556 therefore are more aware of their vulnerability. However, there are many more pedestrians
557 than cyclists, with the World Health Organisation (WHO) estimating that pedestrians account
558 of 22% of all road deaths internationally, with more than 270,000 pedestrian's fatalities per
559 annum (World Health Organisation 2013). Therefore, it is imperative that while advertising
560 needs to be aimed at both cyclists and runners, it is the latter, as well as pedestrians who
561 commonly walk on roads under low light conditions, that need most convincing.
562 Additionally, aspects such as cost and durability were raised as being important factors that
563 play into purchasing behaviour. Concerns regarding whether retroreflective strips would
564 decrease the durability of a garment were also raised.

565

566 An interesting and unexpected finding was the perception of personal safety and conspicuity
567 in low light conditions. Some runners, particularly female runners, expressed the desire to be
568 *invisible* at night when running alone because of the threat of being attacked and so preferred
569 to wear black. Moreover, they talked about feeling safer running next to a busy main road
570 than a road with less traffic. This concept is particularly concerning, as women identified that
571 they wore black to be invisible to potential attackers yet also run next to a busy main road.
572 While main roads may provide the illusion of safety, this is paradoxical, as motorists
573 typically fail to see runners wearing black, thus increasing the risk of a collision on busy
574 roads (Tyrrell et al., 2016).

575

576 While the risk of actually being attacked when running is relatively low, a survey of 2,533
577 women revealed that 58% of women under 30 were subjected to harassment whilst running
578 (Kita and Smith 2017). It seems that for many female runners, being invisible for personal

579 safety reasons outweighs the importance of being visible to oncoming traffic. This is a
580 relevant and pertinent finding that must be explored in future research, in order to evaluate
581 how women can increase their visibility to motorists without compromising their personal
582 safety, and also the role of road lighting in enhancing perceptions of personal safety (Fotios,
583 Unwin et al. 2015). This, however, would be a short-term strategy as in the long term,
584 interventions need to be directed towards the perpetrators in order to change their behaviour
585 and prevent harassment and crime against women in general.

586

587

588 *4.1. Strengths and limitations*

589 The strength of the study was in recruiting participants with a wide range of running and
590 cycling experiences under low light levels and at nighttime from two cities that differ in both
591 climate and cycling uptake. We also included cyclists who commute and also those who
592 cycle only for leisure. However, as with all qualitative studies, there are limitations based on
593 the number of participants. Although nine focus groups is relatively large for a qualitative
594 study, our results are nevertheless based only on 50 people. While the discussions reached
595 saturation (i.e. no further new findings) before the final group, which provided confidence
596 that the results were based on a sufficiently diverse range of experiences, the study is limited
597 in the extent to which it can be generalised to other cities. The small sample size also affects
598 the generalisability of the quantitative findings, and further research with larger, population-
599 based sampling would be useful to further examine the trade-offs between comfort, style, and
600 conspicuity.

601

602 *4.2 Conclusions*

603 In conclusion, we found that cyclists and runners are largely unaware of effective strategies
604 to increase their night-time conspicuity. Importantly, few participants acknowledged the
605 importance of retroreflective clothing in low light conditions, particularly the use of
606 retroreflective strips in the biomotion configuration. In addition, despite being aware of the
607 importance of conspicuity for their safety under low light levels and at night, participants
608 tended to prioritise style or comfort over conspicuity.

609

610

611 *4.3. Future Directions*

612 The lack of recognition of the biomotion effect suggests that future research needs to explore
613 cyclists' and runners' attitudes towards garments which incorporate the biomotion
614 configuration and what would motivate them to wear these garments. Additionally, this study
615 highlighted that more research is needed regarding women's safety at night and how the
616 balance between being visible to motorists and being invisible to potential threats needs to be
617 navigated. Further research is also warranted around climatic variations, where the use of
618 retroreflective biomotion features are restricted for short-sleeved tops and short pants which
619 are often preferred in warm weather. In addition, further research is needed on supporting
620 garment labelling or product information to better enhance consumer knowledge, with the
621 consequential likelihood of increased uptake (purchase) of exercise clothing that increases
622 safety in low light conditions.

623

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