# 1 Contextual cuing in the presence of an overt instruction

2 Tom Beesley1, Louise Earl1, Hope Butler1, Inez Sharp1, Ieva Jaceviciute1, and & David

3 Luque2

4 1 Lancaster University

5 UK

6 2 Universidad de Málaga

7 Spain

# 8 Author Note

9

10 Correspondence concerning this article should be addressed to Tom Beesley,

11 Department of Psychology, Lancaster University, UK, LA1 4YD. E-mail:

12 [t.beesley@lancaster.ac.uk](mailto:t.beesley@lancaster.ac.uk)

13 **Abstract**

14 Three experiments explored the interaction between an endogenous cue of attention and

15 the repetition of a visual search display during contextual cuing. In Experiment 1,

16 participants readily learnt about repeated configurations of visual search, before being

17 presented with an endogenous cue for attention towards the target on every trial.

18 Participants used this cue to improve search times, but the repeated contexts continued to

19 guide attention. Experiment 2 explored whether the presence of the endogenous would

20 impede the acquisition of contextual cuing. It was found that contextual cuing was as

21 strongly acquired in the presence and the absence of the endogenous cue. Experiment 3

22 confirmed the hypothesis that the contextual cuing relies largely on localised distractor

23 contexts. Together, the experiments point towards a seamless interplay between two drivers

24 of attention: visual search was initially guided by the presence of the endogenous cue

25 and then refined by the repeated configurations to facilitate target detection.

26 Public significance statement:

27 *Keywords:* keywords

28 Word count: X

# 29 Contextual cuing in the presence of an overt instruction

30 It is well established that the process of visual search is guided by past experience.

31 When we encounter a scene, the extent to which the configuration of stimuli matches

32 stored representations in memory will determined the effectiveness of the processing and

33 subsequent search through the elements of that scene. This cognitive process is studied in

34 the lab using the contextual cuing (CC) task: participants typically experience a standard

35 visual search task (i.e., serial processing; slow search), such as searching for a T amongst L

36 shapes. A set of search configurations is repeated across trials, and response times to

37 targets are faster compared to those in configurations that do not repeat. Thus, the

38 repetition of the search configurations leads to a stored representation of (some aspect of)

39 the configuration in memory, and future processing of the same configuration activates the

40 memory representation, driving more efficient search behaviour within that scene.

41 Much work has focused on the nature of the cognitive processes

42 responsible for contextual cuing. The effect was initially suggested to be implicit in nature,

43 with repeated configurations seemingly guiding search unconsciously: typically participants

44 are unable to articulate their knowledge of the repeated configurations, and show poor

45 ability to recognise configurations in memory tests (e.g., Chun & Jiang, 1998; Colagiuri &

46 Livesey, 2016), although this view of CC has been strongly contested (e.g., Smyth &

47 Shanks, 2008; Vadillo et al., 2016). There are also a number of plausible models of how

48 memory representations of repeated configurations might guide search (e.g., Beesley et al.,

49 2015; Brady & Chun, 2007), with the predominant view being that the memory

50 representations are best characterised as associative in nature, whereby distractors (or

51 groups of distractors, see Beesley et al., 2016) form associations that activate more likely

52 target positions.

53 The exact nature of how repeated configurations facilitate visual search is also the

54 focus of much debate within the literature. There is a question as to whether CC reflects

55 enhanced attentional processing of the display, such as by reducing the number of

56 distractors processed (e.g., Beesley et al., 2018), or whether it facilitates the decision

57 process once targets have been detected (e.g, Kunar et al., 2007; Sewell et al., 2018). The

58 current article focuses on the assumed attentional advantage for repeated configurations,

59 and explores the extent to which this results in an automatic form of attentional bias.

60 That is, to what extent does the processing of the search configuration control the guidance

61 of attention, and to what extent does that guidance persist even in the presence of other

62 top-down control processes that might be driving attention.

63 A number of studies have explored how flexible the learned behaviours are in

64 contextual cuing. For example, a number of studies have shown that moving the target to

65 a new position within the display will abolish the established CC effect (Makovski & Jiang,

66 2011; Manginelli & Pollmann, 2009). Notably, Zellin et al. (2013) explored the remapping

67 of target positions over a longer training period, observing that with extended training,

68 new associations will form for these new target positions, though the effects are limited to

69 targets that appear closer to those that are initially trained. This suggests that any

70 relocation effect is driven strongly by a generalisation of the pre-existing associations.

71 Furthermore, strong contextual cuing effects were observed for the initially trained targets

72 in a final “return phase” at the end of the experiment. All of these results point towards

73 CC constituting a fairly inflexible behaviour that is activated somewhat automatically

74 during search.

75 More direct examination of the role of top-down control processes on CC comes

76 from Luque et al. (2017) (Experiment 3). They used a task in which participants were

77 initially given a standard CC experiment (search for a T amongst Ls), before then being

78 told in a second phase that the target would appear in two designated positions along the

79 horizontal mid-line of the screen. Participants were given an explicit instruction to search

80 in these two locations for a new target (a Y); in this phase participants engaged in a new

81 search task requiring controlled attention to specified locations. Yet the underlying

82 configuration of repeated distractors was still present, as was the original target, which

83 appeared in its trained location for that configuration. Luque et al. found that the

84 acquired knowledge of the configurations did not affect performance in this second phase:

85 responses to the new target were comparable when the old target was pointed in either the

86 same or opposite direction to the new target, suggesting that there was no detectable

87 processing of the old target (see also Luque et al., 2021). The suggestion is that contextual

88 cuing can be controlled in the presence of a top-down instruction to search in a new

89 location - search is not automatic in nature in the CC task.

90 One potential issue with the studies presented by Luque and colleagues (Luque et

91 al., 2017; Luque et al., 2021) is that participants are instructed to engage in a new search

92 process for a new target object: participants initially search for a T and are later instructed

93 to search for a Y. The role of a prior target template is important for visual search (Vickery

94 et al., 2005; Võ & Wolfe, 2012), and object identities appear to play an important role in

95 the contextual cuing effect (Makovski, 2017, 2018). While it is unclear how dependent CC

96 is on the identity of the target, it is possible that distractor-target associations may well be

97 sensitive to target identity and to the goals of the participant. For this reason, the current

98 study assesses the impact of top-down instruction on CC when participants maintain the

99 same task goal of searching for a single target identity within the display.

100 The overarching aim of the current study is to explore the interaction between

101 controlled (top-down) attentional processes and the pattern of search behaviour established

102 by the repeated configurations. Specifically we seek to understand whether repeated

103 configurations continue to guide attention even when participants are directed to alter their

104 natural search patterns by the presence of an endogenous cue. The experiments explore

105 both the performance aspect of CC in terms of whether it continues to guide behaviour

106 once an endogenous cue is introduced, and also whether the development of the search

107 behaviour is impeded when trained concurrently with the endogenous cue.

# 108 Transparency and Openness

109 The raw data, analysis scripts, experimental materials, and the manuscript source

110 files, are available at <http://github.com/tombeesley/CC_Control>. The analyses reported

111 in this manuscript are computationally reproducible from the manuscript source files (using

112 R v4.1.1), which are available at the github repository. The study design and analyses were

113 not pre-registered.

114 **Experiment 1**

115 Experiment 1 sought to examine whether the learnt attentional behaviour that

116 develops during contextual cuing is expressed when participants are directed by an

117 endogenous (instructional) cue to search in a particular region of the visual scene.

118 Participants were first trained with a set of four repeating configurations in phase 1 across

119 5 epochs of 32 trials each. Then prior to phase 2, participants were told that an arrow

120 would appear before every trial indicating the side of the screen on which the target would

121 be located. This arrow was valid on every trial. In phase 2, the repeating configurations

122 were presented in two forms: “consistent”, where the target appeared in the same position

123 as it has appeared for that configuration in phase 1; and “inconsistent”, where the target

124 appeared in a position in the opposite quadrant of the screen from where it had appeared

125 in phase 1. Random configurations were also presented in this phase. If the contextual cues

126 within the repeated configurations continue to guide attention in the presence of the

127 instructional cue, then we would expect that response times would be faster on consistent

128 trials compared to random trials. In addition, we would also expect that the contextual

129 cues would guide attention *away* from the (new) target quadrant on inconsistent trials, and

130 so response times should be slower on these trials compared to those on random trials.

131 **Method**

132 ***Participants***

133 Thirty-one undergraduate students from Lancaster University were recruited (mean

134 age = 20.13, SD = 1.09; 17 identified as male and 14 as female) via the Psychology

135 Research Participation System in the Department of Psychology at Lancaster University, in

136 return for the opportunity to use the recruitment system for their own research in future

137 years.

138 ***Materials***

139 Participants were tested individually in a quiet room with a Dell laptop with a

140 15.6” screen, a screen resolution of 1920 x 1080, and a full size external keyboard for

141 participants to use to respond to the task. Participants sat approximately 50 cm from the

142 screen. Stimulus presentation was controlled by MATLAB using the Psychophysics

143 Toolbox extensions (Brainard, 1997; Kleiner, Brainard & Pelli, 2007; Pelli, 1997).

144 Responses to the target stimulus were made by pressing the ‘c’ or ‘n’ key on a standard

145 keyboard. All experimental materials are available at the github repository for this study.

146 Distractor stimuli were an ‘L’ shape (rotated 0°, 90°, 180°, or 270°) while the target

147 stimulus was a ‘T’ shape (rotated at either 90° or 270°). Stimuli were XX mm (X.X°)

148 square and arranged in a square grid of 144 evenly spaced cells (12 x 12) which was

149 positioned centrally on the screen and was XXX mm (XX°) square. The grid itself was

150 invisible to participants. The fixation cross (displayed centrally before each trial) was XX

151 mm (X.X°) square. The background of the screen was grey (RGB: .6, .6, .6) and the

152 stimuli were presented in black (RGB: 1, 1, 1). There was a small offset in the vertical line

153 of the ‘L’ distractors, which increased the similarity between the ‘L’ distractors and the

154 target ‘T’, making the search task more difficult (Duncan & Humphreys, 1989).

155 ***Design***

156 Phase 1 employed a within-subjects design with factors of epoch (1-5) and

157 configuration (repeated and random). All configurations contained 16 distractors, equally

158 divided between the four quadrants of the display, and one target. Four repeated

159 configurations were trained. Four target locations were used, with one from each quadrant

160 assigned to each of the repeated configurations. These same four target positions were used

161 for the the random configurations throughout the task. Each of these four target positions

162 was chosen at random from one of five locations within each quadrant, that were

163 approximately equidistant from the center of the screen. Distractors could not appear in

164 these target locations.

165 Phase 2 employed a within-subjects design with factors of epoch (6-10) and

166 configuration (repeated: consistent; repeated: inconsistent; random: consistent;

167 random: inconsistent). On each trial, there was a .5 probability that an “inconsistent”

168 version of the configuration would be presented. This meant that the target was relocated

169 to a diametrically opposed target position such as to maximise the displacement from the

170 trained target position. This could occur for both the repeated and random configurations,

171 hence creating four unique trial types for this phase. While random configurations did not

172 have a “trained”, associated, target position, it is necessary to divide the random trials into

173 consistent and inconsistent trial types in this way in order to assess any target frequency

174 effects that may occur, since the inconsistent target locations used in this phase were novel.

175 ***Procedure***

176 Participants were tested individually in a quiet testing room. They were given

177 instructions on how to complete the task, including the presentation of an example of a

178 search trial. Participants were shown the two correct responses for the two possible

179 orientations of targets.

180 Each trial commenced with a fixation cross presented in the center of the screen for

181 500 ms, which was then replaced immediately by the search configuration. Participants

182 searched for the target stimulus and responded with a left or right response depending on

183 its orientation. Reaction times (RTs) were recorded from the onset of the search

184 configuration. Following a valid response (c or n), the configuration was removed from the

185 screen. The response– stimulus interval (hereafter RSI) was 1,000 ms. If participants made

186 an incorrect response to the target orientation, “INCORRECT RESPONSE” appeared in

187 red in the center of the screen for 3000 ms, prior to the RSI. If participants did not respond

188 within 6000 ms, “TIMEOUT - TOO SLOW” appeared in red in the center of the screen for

189 3000 ms, prior to the RSI.

190 Each block of eight trials contained each of the four different repeated

191 configurations and four random configurations. These eight configurations could appear in

192 any order with the constraint that the position of the target did not repeat across trials or

193 across consecutive blocks.

194 A rest break of 30 seconds was given every 80 trials. Trials started automatically

195 after these breaks.

196 After 160 trials, prior to phase 2, participants were given an instruction screen

197 which detailed the arrow that would appear on the screen prior to the configuration. They

198 were able to ask any questions they had at this stage and then proceeded to phase 2. The

199 arrow appeared for 1000ms following the fixation cross, before the presentation of the

200 search configuration. The task was otherwise identical to that used in phase 1.

201 **Results**

202 Our criterion for removing outlier data, at both the participant level and the trial

203 level, was 2.5 standard deviations above or below the mean of the sample. On average,

204 trials ended with a timeout on 1.97% of trials (SD = 2.53). Two participants had an

205 usually high proportion of timeouts and were removed from the analysis. The mean

206 accuracy of participants (not including timeout trials) was 98.10% (SD = 1.65%). One

207 participant had an unusually low proportion of accurate trials and was also removed. The

208 only participant deemed to be an outlier in terms of mean response time (hereafter RT)

209 was also excluded on the basis of the timeout criterion, noted above.

210 For the remaining twenty-eight participants we removed trials with a timeout and

211 inaccurate trials, before removing outliers from the RT data. On average, the proportion of

212 outliers removed was 3.03% (SD = 0.79%). Zero participants had an unusual proportion of

213 trials removed as outlier RTs.

214 Within-subject error bars were computed by a process of normalising the RT data

215 for the sample (Cousineau, 2005). Figure [1](#_bookmark1) shows the RT data across the 10 epochs of the

216 experiment. In phase 1 (epochs 1-5) a contextual cuing effect rapidly emerged. In phase 2,

217 the presence of the guiding arrow had a dramatic effect on the reduction of response times.

218 For all participants, the mean RT across epochs 4 and 5 was higher than the mean RTs

219 across epochs 6 and 7. Despite the clear evidence for the processing of the endogenous cue,

220 the underlying search configuration continued to play a role in the guidance of attention,

221 with faster response times for (consistent) repeated configurations compared to random

222 configurations.

223 These data were explored with a Bayesian ANOVA, using the

224 *BayesFactor::anovaBF()* function (for all analyses in this study the priors were set at the

225 default “medium” width) 1. First taking the data from phase 1 (epochs 1-5), the model

226 with the largest Bayes Factor (BF) contained the factors of epoch and configuration

227 (repeated vs. random), BF10 = 2.1×1012 ± 1.13%. The addition of the interaction term did

228 not substantially improve the model fit, BF = 0.46 ± 1.95%. The best fitting model was a

1 The Bayesian analyses here follow the process outlined in Rouder et al. (2017). Breifly, we present the best fitting model, followed by a comparison with other models. Where the comparison of two models (i.e., A against B) reveals a Bayes Factor of greater than 3, this is taken as support for the components of model A that are not present in model B. Bayes Factors of less than 0.33 are taken as evidence in support of the equivalence of two models.

2400



Repeated: consistent Repeated: inconsistent Random: consistent Random: inconsistent

2200

2000

1800

RT (ms)

1600

1400

1200

1000

***Figure 1***

1 2 3 4 5 6 7 8 9 10

Epochs of 32 trials

*RT data for Experiment 1*

229 better fit than the two models containing only one of the factors, smallest BF = 35.55 ±

230 1.22%, providing significant support for the effects of configuration and epoch.

231 A Bayesian ANOVA on the data from phase 2 (epochs 6-10) found significant

232 support for the model containing the factor of configuration, BF10 = 89.81 ± 0.8%. The

233 next best fitting model contained the factor of epoch but was a substantially worse fit to

234 the data, BF10 = 0.02 ± 1.16%. Thus there was considerable evidence for an effect of

235 configuration, and evidence that there was no effect of epoch or an interaction between

236 epoch and configuration.

237 To explore the differences in response times across the four trial types in phase 2,

238 the data were averaged across the 5 epochs, and Bayesian t-tests were run using

239 BayesFactor::ttestBF with the default Cauchy prior. This revealed support for a difference

240 between the response times on “repeated: consistent” trials and those on the respective

241 random trials (random: consistent), BF10 = 4.14 ± 0%. There was also evidence to suggest

242 there was no difference between the response times for the “repeated: inconsistent” trials

243 and the respective random trials, BF10 = 0.24 ± 0.03%. There was substantial support for

244 a difference between the response times on repeated consistent and the repeated

245 inconsistent trials, BF10 = 7.87 ± 0%.

246 **Discussion**

247 Experiment 1 sought to examine the consequence of an endogenous cue that

248 prompts top-down control of the search process on contextual cuing. In phase 1 we

249 established a robust contextual cuing effect. Following this, participants received

250 instruction that each trial would be preceded by an arrow stimulus that would signal the

251 side of the screen on which the target would appear. This cue was valid on all trials in

252 phase 2. Consistent with these instructions and the processing of this cue, we observed

253 substantially reduced search times in phase 2 compared to phase 1. The same set of

254 repeated configurations were presented in Phase 2, but for half of the trials, the target was

255 relocated to the diagonally opposed quadrant of the screen. Therefore, on these “repeated

256 inconsistent” trials, the underlying configuration of distractors predicted the target in a

257 location that opposed that of the (valid) endogenous cue. Across this phase we observed

258 significant contextual cuing for the repeated consistent trials, demonstrating that the

259 underlying configuration of distractors continued to guide attention in the presence of the

260 endogenous cue. However, the repeated inconsistent trials did not lead to an impairment in

261 response times relative to random trials, suggesting that the underlying configuration did

262 not influence search on these trials.

263 **Experiment 2**

264 In Experiment 1 we demonstrated that an established effect of contextual cuing is

265 maintained even when attention is being guided by the presence of a valid endogenous cue.

266 That is, we found that the *performance* of an established search behaviour in contextual

267 cuing is not disrupted by concurrent top-down goals to guide attention in a controlled

268 manner. In Experiment 2 we wanted to explore the *learning* of the contextual cue itself,

269 examining whether the presence of a valid endogenous cue may limit the development of a

270 contextual cuing effect. To do this, we trained each participant on two sets of repeating

271 configurations. One of these sets was always presented in the presence of a valid

272 endogenous cue, while the other set was always presented in the absence of the endogenous

273 cue. The extent to which there is a “cue-competition” effect between the endogenous cue

274 and the contextual cues can be examined by comparing the contextual cuing effect we

275 observe for the two sets of configurations. Given the clear difference in RTs we observed in

276 Experiment 1 between the trials with the endogenous cue present and the cue being absent,

277 we anticipated the same difference in responding in Experiment 2. Therefore we also

278 included a second phase of Experiment 2 in which we removed the endogenous cue entirely

279 from the task. This second phase therefore allowed us to directly compare the contextual

280 cuing for the two sets of configurations when RTs were at a comparable level.

281 “Cue-competition” effects have been examined previously in contextual cuing. Endo

282 and Takeda (2004) trained participants with a contextual cuing task composed of

283 distractor location configurations and repeating distractor identities. Their experiments

284 suggested that the stronger configural (spatial) cue out-competed the cue provided by the

285 distractor identities. Similarly, Kunar et al. (2014) found that when colour cues and

286 configural cues both predicted the target location, configural cues were dominant and

287 tended to overshadow the weaker colour cue. Beesley and Shanks (2012) looked at the

288 cue-interaction effects *within* a configuration of distractors. Participants were first trained

289 with half a configuration of repeating distractors that predicted the target (8 out of 16

290 distractors). In a later stage these distractors were paired with a new half-configuration,

291 such that the whole configuration now predicted the same target location. In contrast to

292 the predictions of the vast majority of models of contingency learning, learning about these

293 new predictive distractors was facilitated, rather than impaired in this second phase

294 (relative to a control condition). Thus, Beesley and Shanks (2012) found that

295 cue-competition was not observed within a configuration of equally predictive distractors.

296 Together these studies suggest that the spatial configuration serves as a strong cue for the

297 target and will out-compete non-configural cues for access to the learning mechanism. The

298 dominance of the configuration in these situations may therefore lead to the prediction that

299 the endogenous cue would not “block” the learning of the configuration in this task.

300 **Method**

301 ***Participants***

302 Thirty-four undergraduate students from Lancaster University were recruited (mean

303 age = 20.74, SD = 5.29; 28 identified as male and 6 as female) via the Psychology Research

304 Participation System in the Department of Psychology at Lancaster University, in return

305 for the opportunity to use the recruitment system for their own research in future years.

306 ***Materials***

307 Participants were tested in a quiet laboratory testing cubicle, with a standard PC

308 and a 24” monitor set at a resolution of 1920 x 1080 pixels. All other materials and stimuli

309 were identical to Experiment 1.

310 ***Design***

311 Four repeated configurations were created in an identical manner to those used in

312 Experiment 1. For each participant, two of these configurations were used for the

313 “cue-competition” condition, in which the arrow cue was presented before the

314 configuration, while two were used for the “control” condition (no arrow presented). As in

315 Experiment 1, the four repeated configurations were paired with unique target positions

316 from each of the four quadrants. We counterbalanced the use of the target quadrants

317 across the factors of configuration type (repeated and random) and cue condition

318 (cue-competition and control). For half of the participants, targets in the top left and

319 bottom right were used for the repeated configurations presented with the arrow

320 (cue-competition) condition, with targets in the top right and bottom left used for

321 repeated configurations in the no-arrow (control) condition. For these participants, random

322 configurations presented with the arrow had targets in the top right and bottom left, and

323 random configurations without the arrow had targets in the top left and bottom right. For

324 the other half of the participants these assignments were reversed (repeated-arrow:

325 top-right and bottom-left; repeated-no arrow: top-left and bottom-right; random-arrow:

326 top-left and bottom-right; random-no arrow: top-right and bottom-left).

327 ***Procedure***

328 The procedure was the same as Experiment 1 with the following differences.

329 Participants received 320 trials in total. For the first 160 trials, the arrow was presented for

330 the relevant conditions. For the final 160 trials, the arrow was never presented. Rest breaks

331 were given every 60 trials.

332 **Results**

333 Our criteria for removing outlier data were identical to Experiment 1. On average,

334 trials ended with a timeout on 2.13% of trials (SD = 1.83). Zero participants had an

335 usually high proportion of timeouts. The mean accuracy of participants (not including

336 timeout trials) was 95.85% (SD = 6.10%). One participant had an unusually low

337 proportion of accurate trials and were removed from the sample. Zero participants were

338 deemed to be an outlier in terms of mean RT.

339 For the remaining thirty-three participants we removed trials with a timeout and

340 inaccurate trials, before removing outliers from the RT data. On average, the proportion of

341 outliers removed was 2.81% (SD = 1.04%). One participant had an unusual proportion of

342 trials removed as outlier RTs and were not included in the final analysis.

2800



Repeated: Arrow Random: Arrow Repeated: No arrow Random: No arrow

2600

2400

2200

2000

RT (ms)

1800

1600

1400

1200

***Figure 2***

1 2 3 4 5 6 7 8 9 10

Epochs of 32 trials

*RT data for Experiment 2. Error bars show standard error of the mean on normalised data.*

343 Figure [2](#_bookmark2) shows the RT data across the 10 epochs of the experiment. Contextual

344 cuing emerged rapidly in both the arrow and no-arrow conditions, with little suggestion

345 that the CC effect was different in the two conditions. The Phase 1 data were explored

346 with a Bayesian ANOVA, which revealed that the best fitting model contained the factors

347 of epoch, configuration (repeated vs. random), and endogenous cue (arrow present

348 vs. arrow absent), with no interaction terms, BF10 = 1.1x10101 ± 37.49%. The next best

349 fitting model contained all three factors and the interaction of epoch and configuration,

350 BF10 = 5.5x10100 ± 3.64%, and this model was not a substantially worse fit to the data,

351 BF = 0.48 ± 37.67%. All other models were substantially worse fits than the best fitting

352 model, largest BF = 0.25 ± 4.38%. Importantly, the interaction term between the factors

353 of endogenous cue and configuration did not improve the fit of the model, with support for

354 the absence of this interaction, BF = 0.12 ± 37.57%.

355 When the endogenous cue was removed in the second half of the experiment, RTs

356 were equivalent across the two conditions. An effect of configuration was seen for both

357 cuing conditions, with little discernible difference between the size of the cuing effects. We

358 conducted a Bayesian ANOVA with factors of epoch, configuration and endogenous cue

359 condition (arrow vs. no-arrow). The best fitting model was that with just the factors of

360 epoch and configuration with no interaction between the factors, BF10 = 9.8x1014 ± 2.54%.

361 There was substantial support for this model over the next best fitting model, BF = 8.89 ±

362 4.98%. To examine the interaction of the configuration and endogenous cue factors, we

363 compared the model containing those two factors to the model containing the two factors

364 plus the interaction of configuration and endogenous cue, which revealed support for the

365 absence of an interaction, BF = 0.12 ± 3.36%.

366 To provide further support for the absence of the interaction between the factors of

367 configuration type and endogenous cue, the data from across the experiment (epochs 1-10)

368 were analysed with a Bayesian ANOVA with only the factors of configuration and

369 endogenous cue. The best fitting model was that with the two factors and no interaction,

370 BF10 = 3.7x1051 ± 3.97%. The addition of the interaction term did not strengthen the

371 model, with considerable support evident for the absence of the interaction, BF = 0.1 ±

372 6.49%.

373 **Discussion**

374 Experiment 2 sought to examine whether the presence of a valid endogenous cue

375 would impair the acquisition of a contextual cuing effect. In the first phase, two sets of

376 configurations were trained, one of which was always presented in the presence of the

377 endogenous cue, and one set which was presented without the endogenous cue. Overall

378 there was considerable evidence that the cue was processed and acted upon, as response

379 times to the target were much faster on cued trials. However, there was no evidence to

380 suggest that this initial guidance of attention impaired the acquisition of the configurations

381 on those trials. Furthermore, when the endogenous cue was never presented in the final

382 phase of the experiment, the size of the contextual cuing effect was equivalent between the

383 two sets of configurations; the Bayesian analyses found support for the equivalence of these

384 CC effects.

385 The lack of competition effects seen in Experiment 2 are at odds with some findings

386 in the CC literature (i.e., Endo & Takeda, 2004; Kunar et al., 2014), where competition has

387 been seen by more dominant or salient features of the displays. Instead, the findings point

388 towards a more automatic nature to contextual cuing, whereby associations form

389 ubiquitously, so long as they receive the focus of attention at some point within the search

390 process (e.g., Beesley & Shanks, 2012).

391 Taken together with the findings of Experiment 1, these data suggest that attention

392 can be initially cued in an endogenous manner, before the underlying search configuration

393 refines this attentional process to facilitate search for the target in repeated configurations.

394 The equivalence of the CC effects in the two conditions (cued and uncued) suggests that

395 the guidance by the context was driven largely (or perhaps entirely) by the distractors that

396 appear close to the target. That is, while search times are longer in the uncued condition,

397 and therefore more distractors are inevitably processed in this condition, this additional

398 distractor processing does not result in stronger associative learning. Experiment 3

|  |  |
| --- | --- |
| 399 | explored this hypothesis. |
| 400 | **Experiment 3** |
| 401 | Existing data from studies of contextual cuing has pointed towards a localised |
| 402 | learning effect for repeated configurations, with those distractors closest to the target being |
| 403 | preferentially weighted in the learning process over those located further from the target. |
| 404 | For example, Olson and Chun (2002) trained participants with three sets of repeating |
| 405 | configurations that differed in terms of which distractors repeated across trials. For one |
| 406 | set, the entire global context (all of the distractors) repeated, while for the other two sets |
| 407 | only the short-range (those close to the target) or the long-range distractors (those far from |
| 408 | the target) repeated across trials. They found no difference between the CC effect in the |
| 409 | short-range and global configurations, while the CC effect was not significant for the |
| 410 | long-range context. Similar results have been shown by Brady and Chun (2007) which led |
| 411 | to the development of the spatial constraints model of contextual cuing, in which |
| 412 | distractor-target associations occurring in close proximal space are weighted more heavily |
| 413 | in the learning process (over those occurring across greater spatial distance). |
| 414 | It is important to consider how the bias towards local learning may interact with |
| 415 | the attentional scanning process during contextual cuing. The analysis of eye-movements |
| 416 | during contextual cuing tasks (Beesley et al., 2018; Tseng & Li, 2004) has revealed a |
| 417 | characteristic scanning pattern comprising two phases: search initially occurs in a |
| 418 | seemingly random manner, as the eyes move between distractors in the central region of |
| 419 | the distractor field, before then moving in a more directed manner towards the target |
| 420 | position. Contextual cuing appears to result from a cessation of the first (random) search |
| 421 | phase at an earlier time point in the entire search process, such that processing of repeated |
| 422 | distractors will, on average, result in fewer fixations. With respect to the current study, in |
| 423 | Experiments 1 and 2 we have initially directed attention towards the side of the screen that |
| 424 | contains the target on cued trials. This will bring about an early cessation of the first |

425 phase of the search process. From here, however, it seems that eye-movements are still

426 facilitated by the repetition of the context.

427 To test this characterisation of the interaction between the endogenous cue and the

428 repeated context, we exposed participants to the same procedure as used in phase 1 of

429 Experiment 1, which establishes a contextual cuing effect prior to the use of the

430 endogenous cue. In a second phase we then presented the endogenous cue on every trial (as

431 in Experiment 1), but we manipulated the presence of the repeated distractors within the

432 configurations. For each repeated configuration we created two variations: in the

433 “proximal” configurations, only the distractors in the quadrant containing the target match

434 those from the full repeated configuration, while the distractors in the other three

435 quadrants were randomly arranged on each trial; in the “distal” configurations, the

436 distractors closest to the target were randomised, while the distractors in the other three

437 quadrants were the same as those in the full repeated configuration. During this phase we

438 also presented fully repeated configurations and fully randomised configurations.

439 Comparison of the response times across these four trial types will allow us to determine

440 the contribution of proximal and distal distractors to the CC effect in this task.

441 **Method**

442 ***Participants***

443 Forty-two undergraduate students from Lancaster University were recruited (mean

444 age = 18.64, SD = 2.84; 28 identified as male and 12 as female) via the Psychology

445 Research Participation System in the Department of Psychology at Lancaster University, in

446 return for the opportunity to use the recruitment system for their own research in future

447 years.

448 ***Materials***

449 The experiment was conducted in a quiet testing cubicle, as described in

450 Experiment 2. All other materials and stimuli were identical to Experiment 1.

451 ***Design***

452 The design of phase 1 was identical to Experiment 1, with four repeated

453 configurations created and presented with random configurations during this phase. For

454 Phase 2, each of the four configurations was manipulated to create two alternative

455 conditions. In the “Repeated distal” condition, the four distractors in the target quadrant

456 were randomly arranged on each trial, while the 12 distractors in the other three quadrants

457 were presented in the same positions as had been trained in Phase 1. Thus, slower response

458 times for this condition (compared to the fully repeated configurations) would indicate the

459 extent to which participants CC was governed by the distractors closest to the target. For

460 the “Repeated proximal” condition, the four distractors in the target quadrant were

461 presented in the same positions as had been trained in Phase 1, while the 12 distractors in

462 the other three quadrants were randomly arranged on each trial. Thus, slower response

463 times for this condition (compared to the fully repeated configurations) would indicate the

464 extent to which CC was governed by the distractors further from the target. Comparison

465 of the RTs for these different configurations with those of the random configurations would

466 allow for the assessment of whether these subsets of distractors had *any* contribution to the

467 CC effect that had developed during phase 1.

468 ***Procedure***

469 The procedure was identical to Experiment 1.

470 **Results**

471 Our criteria for removing outlier data were identical to Experiment 1. On average,

472 trials ended with a timeout on 2.81% (SD = 2.25) of trials. Two participants had an

473 usually high proportion of timeouts and were removed from the sample. The mean

474 accuracy of participants (not including timeout trials) was 96.09% (SD = 8.57%). Two

475 participants that had an unusually low proportion of accurate trials and were also removed.

476 Zero participants were deemed to be an outlier in terms of mean RT.

477 For the remaining thirty-eight participants we removed trials with a timeout and

478 inaccurate trials, before removing outliers from the RT data. On average, the proportion of

479 outliers removed was 3.17% (SD = 0.71%). Zero participants had an unusual proportion of

480 trials removed as outlier RTs.

2600



Repeated Random Repeated DISTAL

Repeated PROXIMAL

2400

2200

2000

1800

RT (ms)

1600

1400

1200

1000

***Figure 3***

1 2 3 4 5 6 7 8 9 10

Epochs of 32 trials

*(ref:Exp3-RT-figure)*

481 Figure [3](#_bookmark3) shows the RT data across the 10 epochs of Experiment 3. As in Experiment

482 1, contextual cuing was readily established in Phase 1. These data were subjected to a

483 Bayesian ANOVA which revealed that the best fitting model contained the factors of

484 configuration (repeated vs. random) and epoch, and an interaction between those factors,

485 BF10 = 5.3x1024 ± 1.62%. However, the model without the interaction provided a strong

486 fit to the data, BF10 = 5.1x1024 ± 1.41%, and a comparison between the two models did

487 not find significant evidence in support of the interaction term, BF = 0.97 ± 2.15%. The

488 best fitting model was substantially supported over the remaining models, smallest BF =

489 3868.03 ± 1.7%, providing considerable support for the factors of epoch and configuration.

490 The response times decreased significantly with the presentation of the valid

491 endogenous cue in Phase 2. Response times to the fully repeated configurations were

492 somewhat comparable to those when just the proximal repeated distractors were present.

493 Response times for the distal repeated distractors appeared to be slower and comparable to

494 the fully random configurations. The Phase 2 data were subjected to a Bayesian ANOVA

495 which found that the best fitting model contained the factors of configuration and epoch

496 but no interaction between the factors, BF10 = 1.4x1014 ± 0.95%. This model provided a

497 superior fit to the data compared to the next best fitting model that included the two

498 factors and the interaction term, BF = 123.74 ± 1.61%, providing strong support for the

499 contribution of the two factors and the absence of an interaction between the two factors.

500 Figure [4](#_bookmark4) shows the mean RTs to the four types of configuration, averaged across the

501 5 epochs of Phase 2 (see the Appendix for a plot of these data showing the distribution of

502 individual data points for RT differences). To explore the differences in response times

503 Bayesian t-tests were run for all pairwise comparisons using BayesFactor::ttestBF with the

504 default Cauchy prior. The response times to repeated and repeated-proximal

505 configurations were both faster than those to random configurations, smallest BF10 =

506 10313.81 ± 0%. In contrast, there was no evidence that the response times to

507 repeated-distal configurations were different from those to random configurations, BF10 =

508 0.39 ± 0.04%. Response times to repeated configurations were faster than those to

509 repeated-proximal configurations, BF10 = 4.67 ± 0%. Response times to repeated-proximal

1500

1400

1300

RT (ms)

1200

1100

Repeated

Repeated PROXIMAL

Repeated DISTAL

Random

***Figure 4***

Configuration type

*RT data for phase 2 of Experiment 3. Error bars show standard error of the mean on normalised data.*

510 configurations were faster than those to repeated-distal configurations, BF10 = 31.88 ± 0%.

511 **Discussion**

512 Experiment 3 explored the localisation of the distractors driving contextual cuing

513 when attention is guided initially by an endogenous cue. As expected, there was substantial

514 evidence that contextual cuing was present when the distractors close to the target were

515 maintained, but not when these distractors were randomly arranged. These data provide

516 confirmatory evidence for the hypothesised interplay between the two drivers of attention:

517 initially attention is guided by the endogenous cue towards one half of the screen. Despite

518 visual search never commencing in this manner in the first half of the experiment, a CC

519 effect was readily observed, but only for those configurations in which the local distractors

520 were present. Thus it seems that the stored representations of configurations surrounding

521 target positions are very flexibly deployed in visual search. These data lend support to the

522 notion that the effect of the repeated configuration comes late on in the visual search

523 process, and that each trial commences with a random search process that is not guided by

524 the repeated configuration (Beesley et al., 2018; Tseng & Li, 2004).

# 525 General Discussion

526 Three experiments explored the impact of a central endogenous cue on the

527 contextual cuing of visual search. In Experiment 1, having established a contextual cuing

528 effect, each trial was preceded by an central endogenous cue of attention in the form of an

529 arrow, directing attention towards the side of the screen in which the target was positioned

530 (this arrow cue was always valid in each of the three experiments). Despite participants

531 clearly using this cue, visual search was still facilitated by the presence of the repeating

532 pattern of visual search. This experiment demonstrated that, once acquired, the activation

533 of the memory representation and its impact on performance of visual search remains

534 intact in the presence of a top-down instruction to guide attention. Experiment 2 examined

535 the storage of these contextual representations, and whether these were impaired by an

536 endogenous cue guiding search. We found equivalent levels of contextual cuing for two sets

537 of configurations, one of which was paired with the cue and one which was not. Together,

538 these two experiments suggest a seamless interplay between these two factors governing

539 attention in visual search: the endogenous cue initially guides attention and the repeated

540 configuration continues to refine and guide attention towards a fixation on the target. In

541 Experiment 3 we therefore explored whether the localised distractors around the target

542 were sufficient to generate CC following the guidance by the endogenous cue. Indeed, the

543 CC effect was as large in the case of the proximal distractors compared to the entire

544 repeated configuration of distractors. In contrast, those repetitions that did not contain

545 the proximal distractors failed to generate a CC effect.

546 The effect of CC on visual search has frequently been characterised as an automatic

547 influence on behaviour (e.g., Chun & Jiang, 1998; Chun & Nakayama, 2000; Geyer et al.,

548 2021). This characterisation of CC comes from multiple aspects of the observed effect.

549 Updating of the associations is somewhat slow and seemingly inflexible to changes in the

550 acquired associations (Makovski & Jiang, 2011; Manginelli & Pollmann, 2009; Zellin et al.,

551 2013; e.g., **zellin2011?**), and therefore perhaps reflects a habitual form of behaviour. In

552 addition, contextual cuing has frequently been observed in the absence of above-chance

553 recognition memory for the repeating search configurations (e.g., Colagiuri & Livesey,

554 2016), which suggests a non-conscious, automatically evoked form of behaviour. Despite

555 this persistent characterisation, the automaticity (or controllability) of CC has rarely been

556 directly tested in the literature. To our knowledge, only the experiments of Luque and

557 colleagues (Luque et al., 2017; Luque et al., 2021) have directly assessed this aspect of CC,

558 by placing the influence of the configuration in competition with top-down goals in the

559 task. Their findings supported the conclusion that CC performance can be controlled and

560 will not guide search for the target when another aspect of the task governs attentional

561 control. In the current study, the repeated configurations continued to have an influence on

562 search performance even when attention had been guided by the endogenous cue. These

563 results are therefore somewhat at odds with the conclusions of Luque and colleagues

564 (Luque et al., 2017; Luque et al., 2021).

565 To what extent is this behaviour best characterised as “automatic” in nature?

566 Arguably the clearest demonstration of an automatic effect of a stimulus on behaviour is

567 when the associated behaviour is elicited even when it is counter-productive to the current

568 goals [ref]. Such a test was constructed in the repeated inconsistent trials of Experiment 1,

569 in which the repeated configuration was associated with a target appearing in a position

570 that was in the opposite side of the screen to the direction of the endogenous cue. If the

571 repeated configuration was having an effect on behaviour on these trials we would have

572 expected to see slower response times compared to random trials. This was not the case:

573 response times were equivalent in the two conditions. As such it has hard to claim here

574 that the configuration is having an *automatic* effect on behaviour, according to this strict

575 characterisation of such an effect. Nevertheless, the experiments here reveal an interplay

576 between top-down processes and stimulus driven effects on attention in CC.

577 The current data reveal that the influence of repeated contexts has a relatively late

578 control on behaviour in visual search. Previous analysis of eye-movements during CC

579 (Beesley et al., 2018; Tseng & Li, 2004) has shown that contextual cuing (and visual search

580 more generally) has two characteristic components. The first of these is an inefficient

581 search process where search fails to move towards the target in trials with more fixations.

582 This is followed by a phase in which monotonic, positive increments are made toward the

583 target position in the final 3 to 4 fixations. CC reduces the frequency of trials with the

584 initial (random) search period (there are more of such trials for random configurations and

585 fewer for repeated configurations). Thus, the effect of the endogenous central cue in the

586 current study is to eliminate, or considerably reduce, the engagement with this first phase

587 of the search process. The results of this study strongly imply that the positive associative

588 information in the repeating configurations is extracted in the final stages of search and is

589 localised to the target. This true both in terms of the performance of an acquired

590 configuration (Experiments 1 and 3) and the acquisition of the representation for that

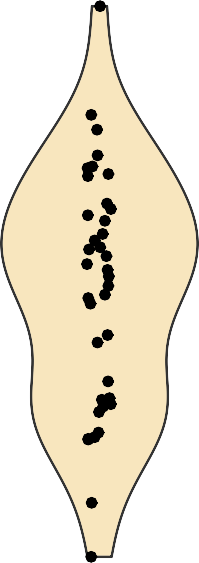
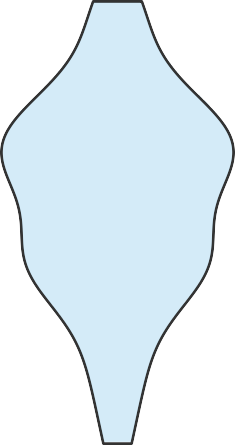
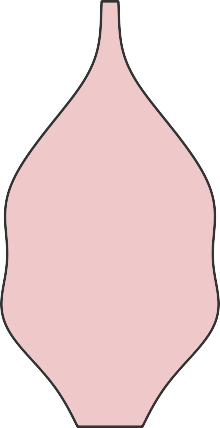
591 configuration (Experiment 2). Perhaps paradoxically, the benefit of repeated configurations

592 in search occurs shortly before the target is fixated.

593 In conclusion. . . .

594 **Appendix**

500



CC effect (RT difference from random)

250

0

-250

***Figure 5***

-500

repeated repeated\_proximal repeated\_distal

TT

*(ref:Exp3-Phase-2-RTdiff-figure)*

595 RT data for phase 2 of Experiment 3. Error bars show standard error of the mean

596 on normalised data. The distribution of RT data for phase 2 of Experiment 3, plotted as

597 difference scores (RT to random configurations minus RT to repeated configuration type).

598 Individual points are presented and linked across trial types.

599 **References**

600 Beesley, T., Hanafi, G., Vadillo, M. A., Shanks, David. R., & Livesey, E. J. (2018). Overt 601 attention in contextual cuing of visual search is driven by the attentional set, but not 602 by the predictiveness of distractors. *Journal of Experimental Psychology: Learning,*

603 *Memory, and Cognition*, *44* (5), 707–721. <https://doi.org/10.1037/xlm0000467>

604 Beesley, T., & Shanks, D. R. (2012). Investigating cue competition in contextual cuing of 605 visual search. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, 606 *38* (3), 709–725. <https://doi.org/10.1037/a0024885>

607 Beesley, T., Vadillo, M. A., Pearson, D., & Shanks, D. R. (2015). Pre-exposure of repeated 608 search configurations facilitates subsequent contextual cuing of visual search. *Journal of* 609 *Experimental Psychology: Learning, Memory, and Cognition*, *41* (2), 348–362.

610 <https://doi.org/10.1037/xlm0000033>

611 Beesley, T., Vadillo, M. A., Pearson, D., & Shanks, D. R. (2016). Configural learning in

612 contextual cuing of visual search. *Journal of Experimental Psychology: Human*

613 *Perception and Performance*, *42* (8), 1173–1185. <https://doi.org/10.1037/xhp0000185>

614 Brady, T. F., & Chun, M. M. (2007). Spatial constraints on learning in visual search: 615 Modeling contextual cuing. *Journal of Experimental Psychology: Human Perception* 616 *and Performance*, *33* (4), 798–815. <https://doi.org/10.1037/0096-1523.33.4.798>

617 Chun, M. M., & Jiang, Y. (1998). Contextual Cueing: Implicit Learning and Memory of

618 Visual Context Guides Spatial Attention. *Cognitive Psychology*, *36* (1), 28–71.

619 <https://doi.org/10.1006/cogp.1998.0681>

620 Chun, M. M., & Nakayama, K. (2000). On the Functional Role of Implicit Visual Memory

621 for the Adaptive Deployment of Attention Across Scenes. *Visual Cognition*, *7* (1-3),

622 65–81. <https://doi.org/10.1080/135062800394685>

623 Colagiuri, B., & Livesey, E. J. (2016). Contextual cuing as a form of nonconscious learning:

624 Theoretical and empirical analysis in large and very large samples. *Psychonomic*

625 *Bulletin & Review*, *23* (6), 1996–2009. <https://doi.org/10.3758/s13423-016-1063-0>

626 Cousineau, D. (2005). Confidence intervals in within-subject designs: A simpler solution to 627 Loftus and Masson’s method. *Tutorials in Quantitative Methods for Psychology*, *1* (1), 628 42–45. <https://doi.org/10.20982/tqmp.01.1.p042>

629 Endo, N., & Takeda, Y. (2004). Selective learning of spatial configuration and object

630 identity in visual search. *Perception & Psychophysics*, *66* (2), 293–302.

631 <https://doi.org/10.3758/BF03194880>

632 Geyer, T., Seitz, W., Zinchenko, A., Müller, H. J., & Conci, M. (2021). Why Are Acquired 633 Search-Guiding Context Memories Resistant to Updating? *Frontiers in Psychology*, *12*, 634 650245. <https://doi.org/10.3389/fpsyg.2021.650245>

635 Kunar, M. A., Flusberg, S., Horowitz, T. S., & Wolfe, J. M. (2007). Does contextual cuing

636 guide the deployment of attention? *Journal of Experimental Psychology: Human*

637 *Perception and Performance*, *33* (4), 816–828.

638 <https://doi.org/10.1037/0096-1523.33.4.816>

639 Kunar, M. A., John, R., & Sweetman, H. (2014). A configural dominant account of

640 contextual cueing: Configural cues are stronger than colour cues. *Quarterly Journal of*

641 *Experimental Psychology (2006)*, *67* (7), 1366–1382.

642 <https://doi.org/10.1080/17470218.2013.863373>

643 Luque, D., Beesley, T., Molinero, S., & Vadillo, M. A. (2021). Contextual cuing of visual

644 search does not guide attention automatically in the presence of top-down goals. 645 *Journal of Experimental Psychology: Human Perception and Performance*, *47* (8), 646 1080–1090. <https://doi.org/10.1037/xhp0000930>

647 Luque, D., Vadillo, M. A., Lopez, F. J., Alonso, R., & Shanks, D. R. (2017). Testing the

648 controllability of contextual cuing of visual search. *Scientific Reports*, *7* (1), 39645.

649 <https://doi.org/10.1038/srep39645>

650 Makovski, T. (2017). Learning “What” and “Where” in Visual Search. *Japanese*

651 *Psychological Research*, *59* (2), 133–143. <https://doi.org/10.1111/jpr.12146>

652 Makovski, T. (2018). Meaning in learning: Contextual cueing relies on objects’ visual

653 features and not on objects’ meaning. *Memory & Cognition*, *46* (1), 58–67.

654 <https://doi.org/10.3758/s13421-017-0745-9>

655 Makovski, T., & Jiang, Y. V. (2011). Investigating the Role of Response in Spatial Context

656 Learning. *Quarterly Journal of Experimental Psychology*, *64* (8), 1563–1579.

657 <https://doi.org/10.1080/17470218.2011.564291>

658 Manginelli, A. A., & Pollmann, S. (2009). Misleading contextual cues: How do they affect

659 visual search? *Psychological Research*, *73* (2), 212–221.

660 <https://doi.org/10.1007/s00426-008-0211-1>

661 Olson, I. R., & Chun, M. M. (2002). Perceptual constraints on implicit learning of spatial 662 context. *Visual Cognition*, *9* (3), 273–302. <https://doi.org/10.1080/13506280042000162> 663 Rouder, J. N., Morey, R. D., Verhagen, J., Swagman, A. R., & Wagenmakers, E.-J. (2017). 664 Bayesian analysis of factorial designs. *Psychological Methods*, *22* (2), 304–321.

665 <https://doi.org/10.1037/met0000057>

666 Sewell, D. K., Colagiuri, B., & Livesey, E. J. (2018). Response time modeling reveals 667 multiple contextual cuing mechanisms. *Psychonomic Bulletin & Review*, *25* (5), 668 1644–1665. <https://doi.org/10.3758/s13423-017-1364-y>

669 Smyth, A. C., & Shanks, D. R. (2008). Awareness in contextual cuing with extended and

670 concurrent explicit tests. *Memory & Cognition*, *36* (2), 403–415.

671 <https://doi.org/10.3758/MC.36.2.403>

672 Tseng, Y.-C., & Li, C.-S. R. (2004). Oculomotor correlates of context-guided learning in

673 visual search. *Perception & Psychophysics*, *66* (8), 1363–1378.

674 <https://doi.org/10.3758/BF03195004>

675 Vadillo, M. A., Konstantinidis, E., & Shanks, D. R. (2016). Underpowered samples, false

676 negatives, and unconscious learning. *Psychonomic Bulletin & Review*, *23* (1), 87–102.

677 <https://doi.org/10.3758/s13423-015-0892-6>

678 Vickery, T. J., King, L.-W., & Jiang, Y. (2005). Setting up the target template in visual

679 search. *Journal of Vision*, *5* (1), 8. <https://doi.org/10.1167/5.1.8>

680 Võ, M. L.-H., & Wolfe, J. M. (2012). When does repeated search in scenes involve memory?

681 Looking at versus looking for objects in scenes. *Journal of Experimental Psychology.*

682 *Human Perception and Performance*, *38* (1), 23–41. <https://doi.org/10.1037/a0024147> 683 Zellin, M., von Muhlenen, A., Muller, H. J., & Conci, M. (2013). Statistical learning in the 684 past modulates contextual cueing in the future. *Journal of Vision*, *13* (3), 19–19.

685 <https://doi.org/10.1167/13.3.19>