

1 Anticipatory versus Reactive Spatial Attentional Bias to Threat

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12 Tel.: +447895625183. Email: thomas.gladwin@gmail.com.13 **Abstract**14 Dot-Probe or Visual Probe Tasks (VPTs) are used extensively to measure attentional biases. A
15 novel variant termed the cued VPT (cVPT) was developed to focus on the anticipatory
16 component of attentional bias. The current study aimed to establish an anticipatory attentional
17 bias to threat using the cVPT and compare its split-half reliability with a typical Dot-Probe task.
18 120 students performed the cVPT task and Dot-Probe tasks. Essentially, the cVPT uses cues that
19 predict the location of pictorial threatening stimuli, but on trials on which probe stimuli are
20 presented the pictures do not appear. Hence, actual presentation of emotional stimuli did not
21 affect responses. The reliability of the cVPT was higher at most Cue-Stimulus Intervals and was
22 .56 overall. A clear anticipatory attentional bias was found. In conclusion, the cVPT may be of

23 methodological and theoretical interest. Using visually neutral predictive cues may remove
24 sources of noise that negatively impact reliability. Predictive cues are able to bias response
25 selection, suggesting a role of predicted outcomes in automatic processes.

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27 Keywords: Threat; attentional bias; anticipatory; cued visual probe; predictive cue

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29 Survival and mental health depend on the ability to efficiently and appropriately respond to
30 threatening stimuli. Spatial selective attention contributes to this ability via attentional biases to
31 threat, broadly defined as the preferential processing of information perceived as threatening
32 (Bar-Haim, Lamy, Pergamin, Bakermans-Kranenburg, & van IJzendoorn, 2007; Cisler & Koster,
33 2010; Mogg & Bradley, 2016). One of the most frequently used paradigms to assess biases in
34 spatial attention is the Dot-Probe or Visual Probe Task (Cisler & Koster, 2010; MacLeod,
35 Mathews, & Tata, 1986; Mogg & Bradley, 2016; Notebaert, Crombez, Van Damme, De Houwer,
36 & Theeuwes, 2011). In this task, two stimuli are presented simultaneously, usually one
37 hypothetically salient and one neutral, with specific stimulus categories depending on the
38 research question. After a short interval, a probe stimulus appears at one of the two stimuli's
39 location, and participants have to respond to the probe. To infer an attentional bias, reaction
40 times are compared between trials in which the probe appears at the location of the negative
41 versus neutral stimulus. Attentional biases involving threat are of interest both as a general
42 feature of human cognition and as a potential contributor to mental health problems such as
43 aggression, anxiety, and post-traumatic stress disorder and depression (Aupperle, Melrose, Stein,
44 & Paulus, 2012; Gladwin, 2017a; Kimonis, Frick, Fazekas, & Loney, 2006; Mogg & Bradley,
45 2016; Yang, Ding, Dai, Peng, & Zhang, 2015; Zinchenko et al., 2017).

46

47 However, measurement procedures involving spatial attentional biases evoked by emotional
48 stimuli will involve a variety of processes, possibly contributing to a number of findings
49 indicating low reliability (Brown et al., 2014; Dear, Sharpe, Nicholas, & Refshauge, 2011; Puls
50 & Rothermund, 2017; Schmukle, 2005; Waechter, Nelson, Wright, Hyatt, & Oakman, 2014).

51 The cues must be perceived, the emotional content must be detected, and this will evoke a

52 subsequent mixture of responses. For example, participants may automatically shift attention
53 towards the threat as expected, but as threatening stimuli are likely also to be aversive
54 participants may tend to avoid them, or be distracted by the stimulus after focusing attention on
55 it. Indeed, complex patterns of attentional shifting appear to occur in the emotional spatial
56 attention tasks, involving time-dependent shifting, selective attention to the probe versus
57 emotional cue after spatial attentional selection, and engagement versus disengagement with the
58 emotional stimuli (Gladwin, Ter Mors-Schulte, Ridderinkhof, & Wiers, 2013; Koster, Crombez,
59 Verschuere, Van Damme, & Wiersema, 2006; Mogg, Bradley, Miles, & Dixon, 2004; Mogg,
60 Holmes, Garner, & Bradley, 2008; Noël et al., 2006; Townshend & Duka, 2007; Vollstädt-Klein,
61 Loeber, von der Goltz, Mann, & Kiefer, 2009).

62

63 Moreover, there is a potentially important element of attention that is not included in this mixture
64 of processes, namely the predictive aspect of threat-related biases. One function of spatial
65 selective attention seems likely to be to focus attention on locations where a threatening stimulus
66 may appear, but has not appeared yet. As an illustration, consider the experience of the person
67 hiding in a room in a horror film, faced with two doors behind one of which the killer might be
68 hiding. Although attentional shifts evoked by actually presented negative stimuli may also
69 involve their predictive value for future events (such as physical harm from some nearby danger
70 being predicted by fearful faces, cf., Hedger, Gray, Garner, & Adams, 2016), the psychological
71 processes in this kind of anticipatory state are intuitively very different from those that occur
72 when the killer actually opens the door, and indeed clear psychophysiological changes occur
73 preceding threatening events (Bolstad et al., 2013; Gladwin, Hashemi, van Ast, & Roelofs, 2016;
74 Kerr, McLaren, Mathy, & Nitschke, 2012; Sussman, Szekely, Hajcak, & Mohanty, 2016). The

75 **anticipatory state** is of theoretical interest from the perspective of models of motivated cognition
76 emphasising the understanding of cognitive processes as reinforcement-based response selection
77 processes aiming to optimize outcome (Alexander, DeLong, & Strick, 1986; de Wit &
78 Dickinson, 2009; Ernst et al., 2004; Gladwin & Figner, 2014; Gladwin, Figner, Crone, & Wiers,
79 2011; Seger, 2008). If even automatic processes involve at least some degree of outcome
80 prediction to select cognitive actions, even if simple and heuristics-based, then attentional biases
81 should also be found before a predicted emotional stimulus, and not only after the actual
82 presentation of one.

83

84 Thus, Visual Probe Tasks (VPTs) designed to focus on this anticipatory attentional state could be
85 of both methodological and theoretical interest. The cued VPT (cVPT), as distinguished from the
86 reactive kind of VPT described above (rVPT), was previously developed to this aim in the
87 context of alcohol-related biases (Gladwin, 2016; Gladwin & Vink, 2017). The cVPT, **illustrated**
88 **in Figure 1**, in a sense combines the Dot-Probe task and Posner cueing tasks (Posner, 1980). In
89 the cVPT trials are divided into Picture trials and Probe trials. On Picture trials, a pair of initially
90 neutral cues (i.e., simple symbols) is replaced, after a variable Cue-Stimulus Interval, by an
91 emotional and a neutral stimulus. One cue is always replaced by the emotional stimulus, and the
92 other cue is always replaced by the neutral stimulus. These trials establish the predictive value of
93 the cues during a training period and subsequently maintain the predictive value of cues. On
94 Probe trials, the cues are followed by a probe stimulus instead of the emotional and neutral
95 pictures, to which participants are required to react pressing a button on the keyboard following
96 task instructions. Cue-related effects on performance on Probe trials are thus caused by the
97 contingency between cues and predicted emotional stimuli (Le Pelley, Vadillo, & Luque, 2013;

98 Luque et al., 2016; Notebaert et al., 2011; Van Damme, Crombez, Hermans, Koster, &
99 Eccleston, 2006), with no emotional stimulus actually being presented at all on that trial. The
100 cVPT has been used to provide novel information on relationships between anticipatory
101 attentional biases for alcohol stimuli, automatic associations and conflict between them, craving,
102 and motives to drink or refrain from drinking (Gladwin & Vink, 2017). It has, however, not been
103 established whether such anticipatory attentional biases exist for threatening stimuli. Further, the
104 visually neutral cues may improve psychometric properties, as effects are due to only two easily
105 distinguishable cues, with presumably no or relatively weak inherent associations that would
106 affect attention, relative to the salience of emotional cues. Thus, the aims of the current study
107 were, first, to determine whether there exists an overall threat-related anticipatory attentional
108 bias; and second, to provide information on the reliability of the cVPT in comparison with an
109 rVPT. We expected that responses would be faster to probes appearing at the location of cues
110 predicting the location of possible threat stimuli versus non-threat stimuli, and that the reliability
111 of attentional bias scores would be higher in the cVPT than in the normal VPT.

112 **Methods**

113 **Subjects**

114 120 healthy adult participants (92 female, 28 male, mean age 20, $SD = 2.1$) successfully
115 completed the online experiment and were included in the analyses. An additional 11 participants
116 were not included, as they either did not finish the full experiment or produced extremely low-
117 quality data, quantified as below chance level (0.5) overall accuracy. Participants provided
118 informed consent, and the study was approved by the institutional ethics committee.

119 **Materials**

120 The tasks were programmed in JavaScript, PHP, CSS and HTML; the code is available on
121 request.

122 **Cued Visual Probe Task (cVPT)**

123 The structure of the cVPT was very similar to the alcohol-cVPT as described previously
124 (Gladwin & Vink, 2017). There was a training phase (4 blocks of 24 trials each) and an
125 assessment phase (24 blocks of 24 trials each, split into two halves to allow the ABBA procedure
126 described below). The phases were identical except for the number of blocks. There were two
127 trial types, randomly selected per trial: Picture and Probe trials. The background colour was
128 black throughout the task. Picture trials started with a fixation cross presented for 100, 200, or
129 300 ms (all such varying durations in the task were selected randomly with equal probability).
130 The fixation cross was followed by the presentation of two cues, located on the top-left and
131 bottom-right of the screen, or on the bottom-left and top-right of the screen. These diagonals on
132 which the cues were located alternated per trial. The cues were coloured blue and yellow and
133 consisted of the symbols O O O O O and | | | | |. The colour-symbol mapping was randomised
134 across participants. Cues were presented for 200, 400, 600, 800 or 1000 ms. The cues were then
135 replaced by pictures representing angry and neutral faces (all male, and all facing forward). One
136 of the cues was always replaced by an angry face centred on the cue location. The other cue was
137 always replaced by a neutral face. The pictures remained onscreen for 1000 ms, followed by 200
138 ms of empty screen. Participants did not have to give any response on Picture trials. The stimulus
139 set consisted of 44 faces selected from the Bochum Emotional Stimulus Set, BESST (Thoma,
140 Soria Bauser, & Suchan, 2013). The mapping of cues to stimulus category was randomised over
141 subjects.

142

143 On Probe trials, the fixation and cue parts of the trial were identical. Instead of pictures
144 appearing at the cued locations, however, a probe stimulus, >><<, was presented at one of the
145 locations, and a distractor stimulus, ^\^ or \V\, at the other location. The probe stimulus was
146 presented for 1000 ms, or until a response was given. The task was to quickly and accurately
147 press a key corresponding to the probe location whenever it appeared. The keys were F R J I,
148 pressed with the index and middle finger of the left and right hands, mapped to the
149 corresponding position; e.g., the R-key was mapped to the top-left position and was pressed with
150 the middle finger of the left hand. On catch trials (5% probability), no probe was presented, and
151 subjects had to refrain from pressing; on these trials, both the presented stimuli were distractors.

152 This was done in order to encourage searching for the probe stimulus rather than possibly
153 attempting to infer the probe location based on viewing a distractor stimulus at the other location.
154 Responses were followed by 200 ms feedback depending on accuracy: a green +1 for correct
155 responses, a red -1 for incorrect responses, and a red “Too late!” if no response was given within
156 the 1000 ms probe presentation duration.

157

158 The use of the two alternating diagonals to present stimuli was done to remove at least some
159 sources of noise due to trial-to-trial carryover effects (Gladwin, 2017a), which were not of
160 interest in the current study; for instance, effects due to giving the same or different response, or
161 responding to the same or different location, on subsequent trials. The varying Cue-Stimulus
162 Interval was included because of the possible time-dependence of attentional biases; for instance,
163 the bias could shift or be stronger or weaker at different time periods following cue presentation.

164 **Reactive Visual Probe Task (rVPT)**

165 The rVPT consisted of a brief introductory phase (two blocks of 24 trials each) and an
166 assessment phase (12 blocks of 24 trials each, split into two parts). The trials of the rVPT were
167 identical to the half of the trials of the Probe trials of the cVPT, except for the use of pairs of an
168 emotional and a neutral stimulus as cues, instead of the predictive cues. The stimuli were the
169 same as those used as pictures in the cVPT.

170

171 **Procedure**

172 Participants performed the experiment online, starting with a page with instructions and an
173 informed consent button. The questionnaires were then filled in. This was followed by the
174 training phase of the cVPT and the introductory phase of the rVPT. Participants subsequently
175 filled in an awareness check to assess whether they were aware of any contingencies between
176 cue and probe location and between cue and pictorial stimuli. Participants were asked the
177 following question: Did they think there was a relationship between cues and probe location? If
178 so, which colour cue predicted the probe location? Did they think there was a relationship
179 between cues and pictures? If so, which colour cue predicted the angry face? If participants did
180 not know the answer, they were instructed to guess. Then the assessment phases of the cVPT and
181 rVPT were then performed, in an ABBA scheme of the four half-parts **of the two VPTs**. The
182 assignment of cVPT and rVPT to the “A” or “B” positions was randomised over participants.
183 This was followed by a repeat of the awareness check. The whole procedure lasted 60 minutes.

184

185 Preprocessing and statistical analyses

186 The first four trials per block, inaccurate trials, and trials following inaccurate trials were
187 removed as these trials are likely to involve abnormal processes.

188

189 An attentional bias score was calculated per participant as the difference between the median
190 reaction time (RT) on probe stimuli appearing at the threat versus at the neutral location. The
191 median was used, as previously in implicit measures of approach-avoidance bias (e.g., Wiers et
192 al., 2016), in order to reduce the impact of outliers (tests using the mean RT are provided in
193 Supplementary Materials, showing highly similar results). One-sample *t*-tests and repeated
194 measures ANOVA were used to test whether there was any bias and whether there was an effect
195 of CSI on bias, respectively. Split-half reliability was tested using the Spearman-Brown formula;
196 the halves consisted of even versus odd blocks. For completeness, we further provide the same
197 tests for effects of accuracy (mean proportion correct).

198

199 Additionally, exploratory analyses intended for future use in planning studies were conducted to
200 investigate correlations between biases and a number of questionnaires. Those results are
201 reported in Supplementary Materials together with their descriptive statistics.

202 Results

203 cVPT

204 As hypothesized, there was an anticipatory attention bias towards threat, $t(119) = -3.88, p < .001,$
205 $d = -0.35$. The magnitude of the bias was -11 ms, indicating a bias towards threat: RT was 566
206 ms when probes appeared at the neutral location and 556 ms when probes appeared at threat

207 location (although 556 – 566 is -10, the bias was -11 ms due to rounding). Essentially, this bias
208 occurred in the absence of the predicted stimuli actually being presented, and must have been
209 due to effects evoked by the predictive cues. There were no effects of CSI.

210

211 The split-half reliabilities were .56 over all CSIs; -.16 for the 200 ms CSI; .48 for 400 ms; .37 for
212 600 ms; .37 for 800 ms; and .41 for 1000 ms.

213

214 Accuracy data showed an effect of threat, responses to probes at the threat location being more
215 accurate than responses to probes at the neutral location ($t(119) = 2.12, p = 0.036, d = 0.19$; the
216 accuracy was .952 versus .944). This effect was modulated by CSI ($F(4, 476) = 4.1, p = 0.0042,$
217 $\eta_p^2 = 0.033$), due to the threat-bias being strongest at 600 ms.

218

219 **rVPT**

220 There was also an attention bias towards threat in the reactive VPT, $t(119) = -4.11, p < .001, d =$
221 -0.38 . The magnitude of the bias was -9 ms, indicating an attentional bias towards threat as well;
222 RT was 530 ms when probes appeared at the location of the neutral cue (the neutral face), and
223 521 ms when probes appeared at the location of the threat cue (the angry face). There were no
224 effects of CSI.

225

226 The split-half reliabilities were .34 over all CSIs; .22 for the 200 ms CSI; .0047 for 400 ms; .031
227 for 600 ms; .19 for 800 ms; and .31 for 1000 ms.

228

229 Accuracy data showed no effects of threat.

230

231 In analyses combining the cVPT and rVPT data in a single model, no significant difference

232 between the task types on attentional bias was found.

233 **Discussion**

234 The current study aimed to determine whether an anticipatory attentional bias to threat could be
235 detected by the cued VPT (cVPT) and to compare its split-half reliability with that of a reactive
236 VPT (rVPT). A clear attentional bias was found on both the cVPT and rVPT. On the cVPT,
237 participants were quicker to respond to probes at the location where a threatening stimulus could
238 have appeared. This anticipatory bias, therefore, does not reflect processes evoked by the
239 viewing of an actual threatening stimulus. It appears that attention is consistently shifted towards
240 a location predicted to reveal a threat. This would appear to make sense from an evolutionary
241 perspective: survival would be enhanced by the ability to use predictive information to focus
242 attention on locations where an as yet unobserved threat could appear. This aspect of *predictive*
243 attentional biases involving emotional stimuli appears to have been understudied thus far,
244 relative to *reactive* attentional biases. However, relatively recent lines of research have focused
245 on anticipatory psychophysiological states under threat (Gladwin et al., 2016; Lojowska,
246 Gladwin, Hermans, & Roelofs, 2015; Löw, Weymar, & Hamm, 2015; Mobbs et al., 2007;
247 Nieuwenhuys & Oudejans, 2010; Wendt, Löw, Weymar, Lotze, & Hamm, 2017). For instance,
248 in a task with a purely anticipatory period in which participants viewed a static screen but
249 awaited a potential virtual attack, heart rate and body sway decreased, reflecting preparatory
250 freezing (Gladwin et al., 2016). It may be fruitful to apply such psychophysiological approaches
251 to threat-related spatial anticipation.

252

253 The prediction of anticipatory attentional biases to threat and the design of the cVPT were
254 derived partly from the R³ model of automatic versus reflective processing (Gladwin & Figner,
255 2014; Gladwin et al., 2011). In this model, cognitive functions, whether “top-down” or “bottom-
256 up”, are selected as any other response, based on associations between stimuli, responses, and
257 outcomes. The time allotted to refining the selection process differentiates relatively reflective
258 from relatively automatic processes, as in the iterative reprocessing model of evaluation
259 (Cunningham, Zelazo, Packer, & Van Bavel, 2007). From this perspective, predictive cues
260 provide foreknowledge of the outcome of shifting attention to or from cued locations, and
261 thereby affect the cognitive response selection process. However, the current data only establish
262 the existence and cue-based measurability of the anticipatory attentional bias for threat, not the
263 underlying mechanisms. An important direction for further study would appear to be clarifying
264 whether anticipatory attentional biases can be attributed to sign-tracking or goal-tracking
265 (Morrison, Bamkole, & Nicola, 2015), and perhaps whether there are interesting individual
266 differences in this regard.

267

268 Split-half reliability was almost uniformly higher in the cVPT than the rVPT, with the exception
269 of the shortest CSI (i.e., 200 ms). This finding was largely as expected, based on the rationale of
270 the removal of noise related to the actual presentation of varying pairs of pictures as cues. One
271 source of noise is that each picture and each picture-pair could have a different effect on bias.
272 Further, as explained in the Introduction, the response to pictorial stimuli could be more noisy
273 due to the complex mixture of processes that could be evoked by their presentation. For instance,
274 a threatening stimulus could draw attention due to fundamental attentional functions (e.g.,

275 directing resources towards likely threat), but also be aversive and therefore cause attention to be
276 shifted away from the stimulus. Unless the temporal dynamics of these processes happen to be
277 such that they can be adequately disentangled by varying the Cue-Stimulus Interval, this would
278 lead to uncontrolled noise might account for the poor reliability scores of the Dot-probe reported
279 in previous psychometric studies (we note this does not imply that every instance of Dot-Probe
280 reliability analyses will be low). By using visually neutral predictive cues, noise may have been
281 reduced, resulting in a more reliable assessment. While the test-retest reliability of the cVPT was
282 still not at the level considered acceptable for questionnaire scales, it was conspicuously higher,
283 in particular at the 400 and 600 ms CSIs. This increase in process purity may, of course, lose
284 interesting information. Recent work has even focused on using the variability itself of
285 attentional bias as a measure of underlying processes (Gladwin, 2016; Iacoviello et al., 2014;
286 Zvielli, Bernstein, & Koster, 2014), such as conflicting evaluative associations (Gladwin &
287 Vink, 2017). Clearly separating such different processes and sources of information would
288 appear to be of importance in future attentional bias studies. We briefly note that advances in
289 behavioural measures for attentional biases are important, in addition to lines of research moving
290 into eye tracking. First, from a theoretical point of view, not all attentional processes are overt
291 and detectable as eye movements. Indeed, EEG studies of spatial attention for instance even
292 depend on the eyes remaining focused on a central fixation point as attention moves covertly.
293 Second, from a pragmatic perspective, behavioural measures allow research to be conducted in a
294 wider range of settings than possible using eye tracking equipment. The field needs to remain
295 open to multiple methods with different advantages and disadvantages. The cVPT will,
296 hopefully, help address the methodological disadvantage of noisy behavioural bias measures.
297

298 A potential application of the cVPT is as a novel version of attentional bias modification (ABM).
299 The same rationale as used in ABM based on manipulated versions of the Dot-Probe (Mogg,
300 Waters, & Bradley, 2017) could be applied to training individuals to shift attention to or away
301 from the predicted location of salient stimuli. Speculatively, an advantage of using the cVPT
302 could be that the training would not paradoxically increase the task-relevance of stimulus
303 categories. This has been termed the salience side-effect (Gladwin, 2017b); note that in usual
304 ABM methods, even if the aim is to train attention away from, for example, threatening stimuli,
305 such stimuli are actually highly salient because they remain informative on the location of the
306 probe. In a training version of the cVPT participants would learn to shift attention based on
307 abstract symbols as cues, not the undesirably salient stimuli themselves. Early results indicate the
308 cVPT may indeed be useful as a training task, and much work indicates that cognitive functions
309 can be assigned to arbitrary cues via reinforcement (McLoughlin & Stewart, 2017), but
310 predictive cue-based ABM as yet remains a direction for future research. A potential issue to be
311 careful of, however, would be the possibility that predictive cues could become aversive due to
312 the training, which would be an undesirable side effect. This should at least be monitored during
313 and following training.

314

315 A limitation of the study is that it remains to be determined whether the results generalise outside
316 the student sample. This population may be relatively skilled at recognising predictive
317 relationships. Even this population was however often unaware of the cue-stimulus
318 contingencies. This does not imply they were unaffected by the contingencies; indeed,
319 exploratory analyses (see Supplementary Materials) did not show any relationships between
320 awareness and bias. Further, the current results do not indicate whether there would be clinical

321 applications of using anticipatory attentional bias, although this would appear to be a clearly
322 interesting direction for further study. An inherent limitation of the cVPT relative to the rVPT is
323 the need for a training period, although it appears that the relatively short training phase used in
324 the current study was sufficient to find a clear bias. However, the training period may also be of
325 interest in itself, for instance by allowing analysis of the time course of the development of the
326 bias. A limitation of the sample was the unequal distribution of female and male participants. It
327 could be informative for future studies to focus on potential gender-related differences in the
328 threat bias. The inclusion of female faces as stimuli could be of particular interest in such studies.
329 A final limitation is that the current study cannot determine the exact mechanisms resulting in
330 the bias. For instance, the current data cannot determine the degree to which the visual features
331 of the cues themselves become emotional stimuli, and whether this plays a causal role in the bias
332 rather than purely their predictive value.

333

334 In conclusion, an anticipatory attentional bias to threat was found using the cued Visual Probe
335 Task. The split-half reliability of this bias was generally higher than the bias evoked by presented
336 emotional cues, as used in more classical paradigms such as the Dot-Probe task. Further studies
337 into the anticipatory attentional bias appear warranted, and the cVPT would appear to be a
338 suitable method for such study.

339 **DECLARATION OF INTEREST**

340 The authors report no conflicts of interest.

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513 Figure 1. Illustration of the cVPT. There were two kinds of trials. On Picture trials, a pair of
514 abstract cues were presented and subsequently replaced by pictorial stimuli: an angry and a
515 neutral face. One of the cues was always replaced by a neutral face, and the other always by
516 an angry face. The location of the cues alternated between the top-left / bottom-right and the
517 bottom-left / top-right diagonal. Picture trials did not require a response. On Probe trials,
518 one of the cues was replaced by a probe stimulus and the other by a distractor stimulus.
519 Participants were required to press the key associated with the probe stimulus.
520