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More than a memory: Confirmatory visual search is not caused by remembering a visual feature

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Abstract

Previous research has demonstrated a preference for positive over negative information in visual search; asking whether a target object is green biases search towards green objects, even when this entails more perceptual processing than searching non-green objects. The present study investigated whether this confirmatory search bias is due to the presence of one particular (e.g., green) color in memory during search. Across two experiments, we show that this is not the critical factor in generating a confirmation bias in search. Search slowed proportionally to the number of stimuli whose color matched the color held in memory only when the color was remembered as part of the search instructions. These results suggest that biased search for information is due to a particular attentional selection strategy, and not to memory-driven attentional biases.

Keywords: Visual attention, Working memory, Visual search, Heuristics, Confirmation bias

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1. Introduction

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The environment is full of information, but from moment-to-moment, we only want answers to particular questions (e.g., is there a car in my blind spot?). Top-down control allows us to attend to information that pertains to our goals; it allows us to selectively query our environment (Schneider & Shiffrin, 1977; Folk, Remington, & Johnston, 1992; Bacon & Egeth, 1994). What questions we ask, and how we ask them, can affect what information is processed and what information is not (Neisser & Becklen, 1975; Simons & Chabris, 1999). Simply asking whether a target object is green will lead observers to attend to green objects, even when non-green objects provide an equal amount of information about the target's color (Rajsic, Wilson, & Pratt, 2015). Thus, top-down visual attention can lead to a sort of confirmation bias (Wason, 1968; Klayman & Ha, 1987) where confirmation occurs faster than disconfirmation. In this paper, we investigate the cognitive mechanisms underlying this bias; specifically, whether the confirmation bias in visual search is an involuntary consequence of holding target information in memory.

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Given that what we need to know about our environment changes from moment-to-moment, it stands to reason that top-down control depends on some sort of short-term memory system that maintains the current attentional criteria. Several models of attention have proposed that memory for attention is enabled by visual working memory (VWM; Luck, 2008), the memory store used to recognize (Luck & Vogel, 1997) and recall (Wilken & Ma, 2004) recently seen visual information (Duncan & Humphreys, 1989; Desimone & Duncan, 1995). Indeed, a considerable amount of evidence shows that maintaining a visual feature in memory for a later test can prioritize processing of objects that possess that feature (Downing, 2000; Soto, Heinke, Humphreys, & Blanco, 2005; Olivers, Meijer, & Theeuwes, 2006; Olivers, 2009; but see

60 Downing & Dodds, 2004; Woodman & Luck, 2007). Such findings lead to an interesting
61 situation; attentional selection that is endogenous (depending on the internal state of the
62 organism, not properties of its input) but also involuntary (not due to current goals of the
63 organism). This is not to say that all top-down control is necessarily of this sort. This memory-
64 driven capture effect is subject to cognitive control (Carlisle & Woodman, 2011; Kiyonaga,
65 Egner, & Soto, 2012), and thus depends on its goal-related utility. Nonetheless, memory-driven
66 attentional capture presents a simple “null hypothesis” of the degree of intention that should be
67 attributed to observers’ attentional control state in a given situation: potentially nothing more
68 than sustaining a memory for relevant information is required for goal-driven selection.

69 As noted earlier, a consequence of top-down attention is that information outside of the
70 attentional set may be missed (Simons & Chabris, 1999; Lavie & Tsal, 1994). Recently, we have
71 shown that this failure can take the form of a confirmation bias: when asked whether a target
72 object has a particular property or not (e.g., is green or not green), attention is biased towards
73 objects with this property (Rajsic et al., 2015). To do so, we have used a search task where two
74 colored variants of a target can appear in search, for example, either a red or a green p among red
75 and green non-p’s (d, b, and q’s). On every trial, one, and only one, of the two targets is present.
76 Critically, participants are instructed to report whether the target letter is a particular color or not
77 (e.g., is the p green or not). This allows one color to provide “positive information” and the other
78 color to provide “negative information” with respect to the tested proposition (Klayman & Ha,
79 1987). What we are interested in is whether visual search will exhibit a bias towards positive
80 information; that is, whether search times will depend on the number of matching colors (i.e., the
81 number of green letters, in the example given), as search for color-defined targets can be
82 restricted to color subsets (Egeth, Virzi, & Garbart, 1984; Bacon & Egeth, 1997). Our previous

83 investigations (Rajsic et al., 2015; Rajsic, Taylor & Pratt, 2016; Rajsic, Wilson, & Pratt, 2017)
84 have shown that a bias towards positive information does win out over the alternative strategy of
85 attending to the smaller color subset (Sobel & Cave, 2002).

86 In our previous work, we have suggested that this confirmation bias results from a default
87 strategy for testing hypotheses, whether perceptual or otherwise, of attending to features of the
88 positive predictions of a proposition (Klayman & Ha, 1987). Consistent with this, the bias in
89 search is reduced when searches are made more inefficient (Rajsic et al., 2017) and also when
90 tested propositions tend to be false (e.g., targets tend to be non-green; Walenchok, Hout, &
91 Goldinger, 2016). However, in light of the phenomenon of memory-driven attention reviewed
92 earlier, a simpler explanation may exist. Given that participants need to at least encode, if not
93 remember, one of the two stimulus colors to make responses in the search task, it is possible that
94 the bias towards positive information is solely due to the consonance between a color held in
95 memory (presumably VWM, although a verbal code can produce memory-driven capture as
96 well: Soto & Humphreys, 2007) and not because of a hypothesis testing strategy. For example,
97 when asked to report whether a p is green or not, participants may adopt a top-down set for the
98 smaller color subset (i.e., red or green letters, whichever there are fewer of), but the necessity of
99 maintaining the feature “green” in working memory to code the temporary stimulus-response
100 mappings could cause green items to capture attention involuntarily during searches. In the
101 present paper, we present two experiments testing this alternative explanation for the
102 confirmation bias. To preview our findings, in both experiments, we find no evidence of
103 selective search through stimuli whose color matches a color merely held in memory, suggesting
104 that there is more to confirmatory search than the contents of memory.

105 **2. Experiment 1**

106 The goal of Experiment 1 was to test the possibility that confirmatory visual search is a
107 result of one of two colors being held in working memory. To accomplish this, we adapted the
108 design of Experiment 1 of Rajsic et al., (2015) to contrast the instructional manipulation that we
109 presume to underlie confirmatory searching (the Positive information condition) with a stimulus-
110 matched version that required similar maintenance of a color in memory (the Working Memory
111 condition), but did not afford confirmatory searching.

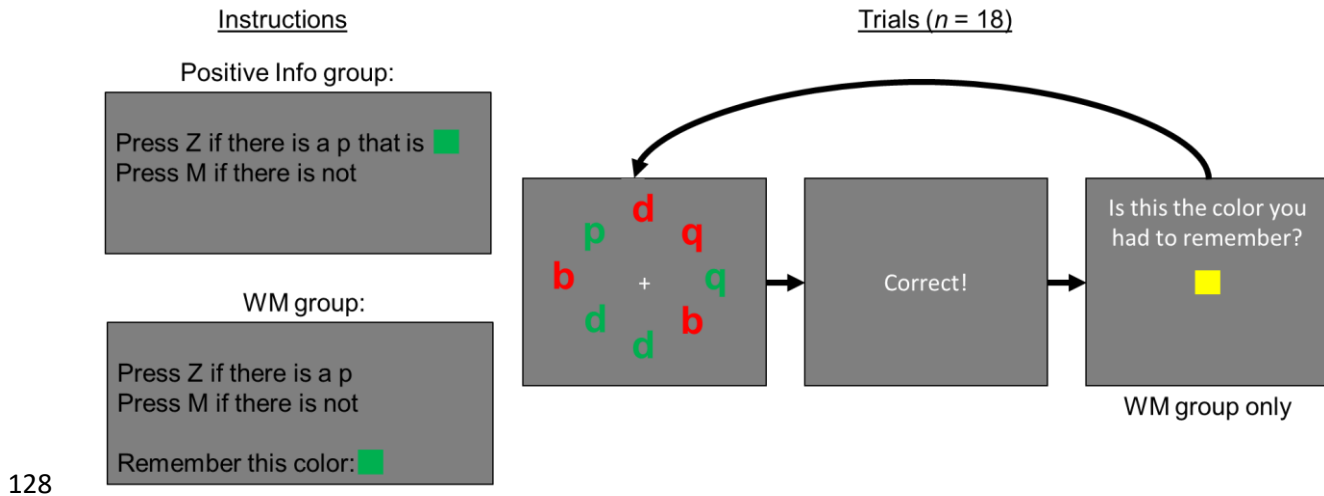
112 **2.1 Methods**

113 **2.1.1 Participants**

114 Thirty-two undergraduate students enrolled in a first-year Psychology course at the
115 University of Toronto volunteered for Experiment 1 through an online system. Students did not
116 know the nature of the study for which they had volunteered until arriving at the lab, at which
117 point the procedure was explained and informed consent was given. Participants were
118 compensated for their participation with partial course credit. Half of the participants ($n = 16$)
119 participated in the positive information condition, and half participated in the working memory
120 condition.

121 **2.1.2 Stimuli and Procedure**

122 Stimuli were presented using 16" CRT monitors on a Dell PCs using Matlab and the
123 Psychophysics Toolbox (Kleiner, Brainard, & Pelli, 2007). Responses were collected with a
124 standard USB keyboard. The experiment consisted of a series of displays; instruction displays,
125 that presented participants with search instructions before each block of trials an experimental
126 session, and trials displays, which comprised individual trials. A schematic depiction of these
127 displays is presented in Figure 1.



128

129 **Figure 1.**

130 A schematic of the events in Experiment 1. Instructions were presented before each block of 18
 131 trials. Stimuli are not drawn to scale.

132

133 Before beginning the experiment, the experiment program displayed a written description
 134 of the task, which was closely matched between the two conditions. Both instructions
 135 emphasized that two possible target colors would be used. Participants pressed Enter to move
 136 past this screen, with a minimum 3-second duration.

137 Instruction displays for the positive information condition consisted of the instruction
 138 “Press *a* if the *target* is this colour: *color*. Press *b* if it is not.” printed in the upper left of the
 139 screen. Instruction displays for the working memory condition used the instruction “Press *a* if the
 140 *target* is present. Press *b* if it is not.” For both instruction types, the keys Z and M were used in a
 141 counterbalanced order to stand for responses *a* and *b*, and the *target* letter could be either p, b, d,
 142 or q. For the positive information condition, the *color* consisted of a small (1° by 1°) square
 143 colored in with the RGB coordinates of the template-matching color used for all subsequent
 144 search displays for that instruction. Instruction displays were presented until the participant

145 pressed the Enter key to begin the experiment, with a minimum 1-second duration to ensure the
146 instructions were not skipped by accident.

147 Each trial began with a fixation display, for 2000ms, consisting of a white + symbol,
148 subtending 0.8° by 0.8° , on a dark grey background. The search display followed, with an
149 identical fixation mark and 8 search letters (p, d, b, and q), positioned evenly around the
150 circumference of an imaginary circle, radius 8° , centered on fixation. The letters subtended
151 approximately 0.8° in width and 1.2° in height and were printed in Arial font.

152 On Target Present trials, one of the letters was the target letter, and the other seven
153 distractor letters were chosen from the three remaining letters, randomly sampled with
154 replacement. On color-matching trials, the target appeared in the color presented during the
155 instructions. On color-mismatching trials, the target appeared in the color not presented during
156 the instructions. On Target Absent trials, all distractors were selected from the three non-target
157 letters.

158 The colors of the search stimuli were also manipulated in three levels, orthogonally to the
159 target present factor. Before each search instruction display, two colors were selected to be used
160 for a search block: one color to be presented in the instruction and one that would not, from a
161 pool of seven colors (purple, yellow, green, orange, pink, blue, and red; see Rajsic et al., 2015
162 for RGB values). Either two, four, or six of the letters were colored using the color presented in
163 the instructions, with the remaining letters colored in the color not presented. The search display
164 was presented until a response was provided, using the Z or M keys. Once a response had been
165 given, a feedback display appeared, with the word “Correct!” or “Incorrect” displayed at the
166 center of the screen. This display lasted for 2000ms. In the working memory condition only, a
167 memory test display followed this feedback screen. The memory test screen presented a single

168 colored square, 1° by 1° , whose color either matched the remembered color or did not (i.e., it
169 was selected from one of the six non-remembered colors). A memory response prompt was
170 presented 12° above fixation, asking “Is this the colour that you had to remember? Z = yes, M =
171 No.”, centered horizontally. On half of the trials, the color matched the remembered color, and
172 on half it did not. After a response was provided, the next trial began immediately.

173 Participants completed 16 blocks of 18 trials, where each block began with a new
174 instruction screen. Within a block, the 18 trials were composed of an equal distribution of the
175 three target present conditions and the three template color match conditions (i.e., 3 trials of
176 each) in a random order.

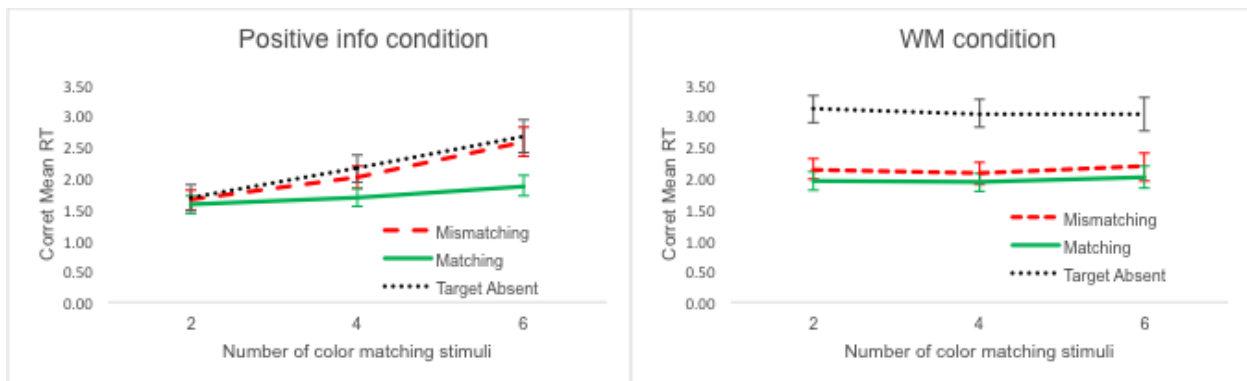
177 **2.2 Results**

178 Our primary unit of interest was correct response time for each condition. Trials were
179 selected for inclusion as long as responses were correct, and as long as response times were not
180 greater or less than three standard deviations from each participant's average correct response
181 time. For the working memory condition, an additional constraint was added: memory responses
182 at the end of the trial needed to be correct. In addition, three participants from both conditions
183 were excluded for having an overall accuracy of less than 75% (statistical results were similar
184 without these participants' exclusion). In the positive information condition, 10.6% of trials, on
185 average, were excluded due to incorrect search responses and 1.6% of trials, on average, were
186 excluded for slow responses. In the working memory condition, 11.7% of trials, on average,
187 were excluded due to incorrect search responses, 1.1% of trials were excluded due to slow
188 responses, and 2.8% of trials were excluded due to incorrect memory responses. Overall, 11.7%
189 of trials were excluded in the positive information condition and 15.1% of trials were excluded in
190 the working memory condition.

191 Mean correct response times were calculated for each cell of our design: Target Presence
192 (color matching, color mismatching, target absent) by Color Subset (2 matching, 4 matching, or
193 6 matching), and analysed with a 3 x 2 x 2 mixed model ANOVA, with the instruction condition
194 included as a between-subjects factor. Search bias, as assessed by the color subset factor,
195 differed by search instruction, $F(2, 48) = 39.15, p < .001, \eta^2_p = .62$, as did the target presence
196 effect, $F(2, 48) = 29.59, p < .001, \eta^2_p = .55$, and their interaction, $F(4, 96) = 9.55, p < .001, \eta^2_p =$
197 .29.

198 As can be seen in Figure 2, search under the positive information instructions closely
199 resembled a serial search *for* targets matching the color held in memory: the target absent ($M =$

200 233ms, $SE = 27$ ms) and color mismatching search slopes ($M = 248$ ms, $SE = 27$ ms) were
 201 approximately double those of color matching search slopes ($M = 75$ ms, $SE = 19$ ms). In contrast,
 202 in the working memory condition, search slopes were considerably flatter ($M_{\text{match}} = 16$ ms, SE_{match}
 203 $= 19$ ms, $M_{\text{mismatch}} = 10$ ms, $SE_{\text{mismatch}} = 27$ ms, $M_{\text{target absent}} = -20$ ms, $SE_{\text{target absent}} = 27$ ms). For both
 204 instruction conditions, however, color matching targets were reported faster than color
 205 mismatching targets. When targets matched the color in the search instructions, color matching
 206 targets were reported faster, $M = 1709$ ms, $SE = 157$ ms, than color mismatching targets, $M =$
 207 2075 ms, $SE = 232$ ms, $F(1, 12) = 15.183$, $p = .002$, $\eta^2_p = .56$. When colors were simply held in
 208 memory, memory matching targets were still reported faster, $M = 1959$ ms, $SE = 146$ ms, than
 209 memory mismatching targets, $M = 2124$ ms, $SE = 135$ ms, $F(1, 12) = 10.01$, $p = .008$, $\eta^2_p = .46$.



210
 211 **Figure 2.** Search performance in Experiment 1 as a function of instruction type (left and right
 212 panels), target type, and color subset size. Error bars depict one within-subjects standard error
 213 (Cousineau, 2005).

214

215 2.3 Discussion

216 Overall, the results of Experiment 1 show that confirmatory search patterns are not
 217 simply a function of having to maintain a particular visual feature in memory during search.

218 Search slopes over the memory-matching color subset were considerably steeper when

219 participants were asked to report the presence of a particular colored target than when they were
220 asked to search for a particular target while holding a color in memory. However, targets
221 matching the color held in memory (for the search task, or merely during the search task) were
222 reported faster in both cases. Nonetheless, the results clearly support the conclusion that a search
223 setting requires more than a particular color being stored in memory.

224 **3. Experiment 2**

225 Although the results of Experiment 1 demonstrated that confirmatory search patterns are
226 unlikely to be due simply to a color being stored in memory, the inclusion of target absent trials
227 could have compromised our measure of the extent of the subset slope difference. In our original
228 experiments (Rajsic et al., 2015), the target letter was always present. This was a very important
229 design implementation, as it allowed for the existence of negative information (i.e., information
230 that could negate one perceptual hypothesis). By including target absent trials in Experiment 1,
231 this considerably reduced the utility of negative information; while it was true that finding a
232 color mismatching target allowed the correct inference that a color matching target was not
233 present, failing to find a given target did not allow for the inference that the other target was
234 present. For this reason, the search strategy observed in our positive information condition in
235 Experiment 1 cannot be clearly deemed a bias; a correct “yes” response can only be given by
236 encountering a matching target, making a bias towards this color reasonable.

237 In Experiment 2, we modified the design of Experiment 1 so that only target-present
238 trials were used, as in our previous work (Rajsic et al., 2015). For the working memory
239 condition, participants discriminated the hemifield (left or right) that the target appeared in. As in
240 Experiment 1, if confirmatory search patterns are simply due to the maintenance of a particular

241 color in working memory, we should observe a matching-subset search slope in both the positive
242 information and working memory conditions.

243 **3.1 Methods**

244 **3.1.1 Participants**

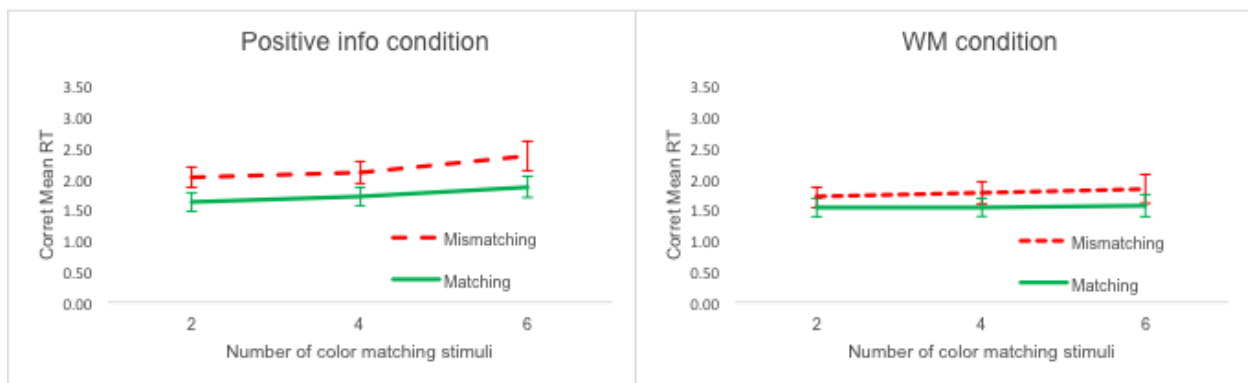
245 Twenty-four undergraduates enrolled in a first-year Psychology class at the University of
246 Toronto participated in Experiment 2. None of the participants in Experiment 2 had participated
247 in Experiment 1. Half of the participants (12) participated in the positive information condition,
248 and the other half participated in the working memory condition. All participants gave informed
249 consent before participating.

250 **3.1.2 Stimuli and Procedure**

251 The apparatus used in Experiment 2 were identical to those used in Experiment 1. The
252 stimuli as well were identical with the following exceptions: the instructions of Experiment 2
253 were changed to reflect the new task, emphasizing the fact that the target letter would always be
254 present in the display. In addition, before each block of trials, search instructions were given as
255 “Press *a* if the *target* is this colour: *color*. Press *b* if it is not.” for the positive information
256 condition, and “Press *Z* if the *target* is on the left. Press *M* if it is not” for the working memory
257 condition. The trials were also adjusted by removing all target absent trials. As such, the number
258 of trials was reduced (16 blocks of 12 trials). Finally, to allow all targets to be reported as being
259 on the left or right in the WM condition, stimulus positions were rotated by 22.5° (around
260 fixation), such that all stimuli appeared in either the left or right hemifield.

261 3.2 Results

262 Trials for analysis were selected using the same procedure as Experiment 1; only trials
 263 with accurate responses and responses that fell within three standard deviations of participants'
 264 respective mean correct response time were included. For the positive information condition, this
 265 led to the exclusion of 12.3% of trials on average per person, comprising 1.9% slow responses
 266 and 11.1% search errors, and 10.5% of trials on average per person in the working memory
 267 condition, comprising 1.0% slow responses, 4.6% search errors, and 5.4% memory errors. The
 268 resulting search data are plotted in Figure 3.



269 **Figure 3.** Search performance in Experiment 2 as a function of instruction type (left and right
 270 panels), target type, and color subset size. Error bars depict one within-subjects standard error
 271 (Cousineau, 2005).
 272

273
 274 As in Experiment 1, our critical interest was in whether the subset slopes differed
 275 between the two conditions. A mixed-model ANOVA showed an interaction between search
 276 condition and color matching subset size, $F(2, 44) = 5.11, p = .01, \eta^2_p = .19$. For the positive
 277 information condition, search slopes were steep, but near parallel ($M_{\text{color matching}} = 63\text{ms}, SE_{\text{color}}$
 278 $\text{matching} = 14\text{ms}, M_{\text{color mismatching}} = 84\text{ms}, SE_{\text{color matching}} = 22\text{ms}$). In the working memory condition,

279 slopes were considerably less steep, $F(1, 22) = 9.86, p = .005, \eta^2_p = .31, (M_{\text{color matching}} = 8\text{ms},$
280 $SE_{\text{color matching}} = 14\text{ms}, M_{\text{color mismatching}} = 34\text{ms}, SE_{\text{color matching}} = 22\text{ms})$.

281 Despite the lack of a strong bias towards color-matching stimuli in the working memory
282 condition, we nonetheless observed an advantage in response time for matching-targets, $M =$
283 $1538\text{ms}, SE = 72\text{ms}$, over mismatching targets, $M = 1766\text{ms}, SE = 105\text{ms}, F(1, 11) = 11.34, p =$
284 $.006, \eta^2_p = .51$.

285 **3.3 Discussion**

286 Experiment 2 demonstrated that, in a search for targets that were always present,
287 confirmatory search emerged when one color was framed as positive information, but not when
288 that same color was simply held in memory. Only in the former condition did search slopes
289 clearly indicate a selection of matching-colored search items. However, in both conditions, we
290 observed an overall advantage in the speed of reporting a memory-matching target.

291 **4. General Discussion**

292 The goal of the present investigation was to determine whether confirmatory visual
293 search occurs because of the need to maintain particular visual information in memory. Given
294 that asking whether a target object has a particular property (e.g., greenness) requires
295 remembering the property in question (green), this memory representation alone could lead to
296 confirmatory search patterns if it involuntarily drove attention to matching visual information
297 (Soto, Heinke, Humphreys, & Blanco, 2005; Soto & Humphreys, 2007). Across two
298 experiments, we showed that this is not the case. With identical search displays, searches were
299 biased to particular colored stimuli only when searchers were asked about whether a target had a
300 particular feature (the positive information condition), but not when they were asked to search

301 for a target while remembering that same feature (the working memory condition). These results
302 show that confirmatory search is not simply due to feature-priming (see also Rajsic et al., 2016).

303 One noteworthy observation from the present experiments is that while a search slope
304 over feature-matching stimuli occurred only in the positive information condition, both
305 conditions showed a response-time benefit when the target possessed the feature maintained in
306 memory. We take this to reflect the involvement of features held in memory in the target
307 recognition stage of search, but not in the guidance stage. Recent evidence shows that variations
308 in the precision, category, and prevalence of target types can affect both guidance and the speed
309 of recognition (Hout & Goldinger, 2015; Hout, et al., 2017; Hout, Walenchok, Goldinger, &
310 Wolfe, 2015). Repetition benefits for conjunction targets and distractor context also seem to
311 largely produce intercept, not slope, changes in visual search (Kristjánsson, Wang, & Nakayama,
312 2002; Kunar, Flusberg, Horowitz, & Wolfe, 2007; but see Becker & Horstmann, 2009).

313 Interpreted through the lens of a two-stage search theory, like Guided Search 4.0 (Wolfe, 2007),
314 our results suggest that, at least in our task, activating a feature in working memory affects the
315 speed of object recognition, either by lowering a “target” threshold for objects possessing
316 features in working memory, or by increasing the rate of “target” evidence accrual for object
317 whose features match those in working memory; our experiments were not designed to provide
318 the detailed speed-accuracy data needed to tease these two possibilities apart. Importantly, our
319 data suggest that settings of the guidance system are, appropriately, related to the search task and
320 not the contents of memory. Even memory-driven capture effects are affected by task-demands
321 (Carlisle & Woodman, 2011; Olivers & Eimer, 2011; Dalvit & Eimer, 2011; Kiyonaga, Egner, &
322 Soto, 2012), demonstrating that the information currently held in memory is only part of the
323 process of allocating visual attention (if at all: Woodman, Carlisle, & Reinhart, 2013).

324 It thus seems clear that there is more to the guidance of attention than information
325 maintained in memory: but what else is involved? Given that working memory representations
326 are considered to be the format shared by many cognitive operations (Luck, 2008), there must be
327 additional states or processes that code the current function, or use, of the information
328 maintained in memory. Indeed, this would mirror the way we talk about these cognitive activities
329 (e.g., I can search for red or for green objects, and I can also list foods I know of that are red or
330 green). Oberauer (2010) referred to this second set of functions as procedural working memory,
331 and suggests that cognitive actions are the result of cognitive bindings between the content (red)
332 and the conduct (look-for), both maintained in short term memory stores. This proposal would
333 make similar predictions to the “special status” proposal of Olivers, Peters, Houtkamp, and
334 Roelfsema (2011), who proposed that only one working memory representation can guide
335 attention at a time, if it were the case that only one binding could be maintained. However,
336 available empirical evidence suggests that the one-item limit is not always observed (Beck,
337 Hollingworth, & Luck, 2012; Hollingworth & Beck, 2016), though it is not clear whether
338 multiple-feature templates should be considered one or several templates (Huang & Pashler,
339 2007). We suggest, along with Irons and Leber (2016), that the relative utility of different
340 attentional guidance strategies may be critical in resolving these issues.

341 To be clear, although our results show that maintenance of a color in memory is not
342 sufficient to induce a visual confirmation bias, active working memory representations might
343 nonetheless be the source of the bias when memories are relevant to search (i.e., when they are
344 involved in maintaining features of the search instructions). We follow previous researchers in
345 suggesting that voluntary attentional guidance requires additional cognitive processes (Olivers &
346 Eimer, 2011; Carlisle & Woodman, 2011). A recent discussion of internal attention by Myers,

347 Stokes, and Nobre (2017) provides a useful perspective on this issue by highlighting how an
348 “attended memory” may be better thought of in terms of reformatting a memory to prepare for
349 particular tasks and actions. They suggest that the difference between remembering several
350 colors for a memory test and focusing one of those colors that has been cued as likely to be
351 tested may be a change in the temporary mappings between representations of remembered
352 colors and potential responses (same/different from any color, same/different from cued color).
353 Our results are quite compatible with this line of reasoning; this is, after all, our primary
354 manipulation. Similar manipulations of remembering versus implementing instructions during a
355 stimulus-response task have revealed considerable neural differences between these two
356 cognitive states, both in terms of regions associated with control (e.g., lateral prefrontal and
357 parietal cortices) and regions associated with stimulus coding (e.g., visual areas, such as the
358 fusiform face area; Muhle-Karbe, Duncan, De Baene, Mitchell, & Brass, 2016). We suggest that
359 top-down guidance of visual attention may be a special case of this broader class of memory-
360 action couplings.

361 In referring to the search patterns we have observed as a “confirmation bias”, we are
362 suggesting that participants’ lack of flexible subset selection in our task amounts to a failure to
363 actively entertain alternative perceptual hypotheses (Kunda, 1990; Koehler, 1991; Mynatt,
364 Doherty, & Dragan, 1993; Buttaccio, Lange, Thomas, & Dougherty, 2015). Ruling out a simple
365 memory-driven attentional bias explanation provides some support to this interpretation. As
366 such, we consider our results to be indicative of the cognitive strategies participants employ in
367 visual search, and, perhaps too, other forms of visual reasoning. The notion that confirmatory
368 searches are a simple, default method of querying visual data is congruent with research on
369 sentence-picture comparisons, where verifying that a previously presented sentence described a

370 picture tends to be faster than denying the match (Clark & Chase, 1972; but see Underwood,
371 Jebbett, & Roberts, 2004) as well as recent work on the interpretation of graphical data
372 representations by Michal and colleagues (Michal, Uttal, Shah, & Franconeri, 2016), which
373 shows a tendency to inspect graphs in the order suggested by a question.

374 To conclude, the present study shows that the confirmation bias in search is not the result
375 simply of the contents of memory. We suggest instead that it reflects an information search
376 strategy (i.e., template-matching) that allows for a cognitively economical solution to visual
377 hypothesis testing.

378

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