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.

1. Introduction

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 (Bacon & Egeth, 1994; Folk, Remington, & Johnston, 1992; Shiffrin & Schneider, 1977). 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 (Klayman & Ha, 1987; Wason, 1968) 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.

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 (Desimone & Duncan, 1995; Duncan & Humphreys, 1989). 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 Downing & Dodds, 2004; Woodman & Luck, 2007). Such findings lead to an interesting situation; attentional selection that is endogenous (depending on the internal state of the organism, not properties of its input) but also involuntary (not due to current goals of the organism). This is not to say that all top-down control is necessarily of this sort. This memory-driven capture effect is subject to cognitive control (Carlisle & Woodman, 2011; Kiyonaga, Egner, & Soto, 2012), and thus depends on its goal-related utility. Nonetheless, memory-driven attentional capture presents a simple "null hypothesis" of the degree of intention that should be attributed to observers' attentional control state in a given situation: potentially nothing more than sustaining a memory for relevant information is required for goal-driven selection.

As noted earlier, a consequence of top-down attention is that information outside of the attentional set may be missed (Lavie & Tsal, 1994; Simons & Chabris, 1999). Recently, we have shown that this failure can take the form of a confirmation bias: when asked whether a target object has a particular property or not (e.g., is green or not green), attention is biased towards objects with this property (Rajsic et al., 2015). To do so, we have used a search task where two colored variants of a target can appear in search, for example, either a red or a green p among red and green non-p's (d, b, and q's). On every trial, one, and only one, of the two targets is present. Critically, participants are

Positive Info group:

Press Z if there is a p that is ▮

Press M if there is not

d q

p q

b + q

d b

d

Correct!

Is this the color you had to remember?

▮

WM group only

WM group:

Press Z if there is a p

Press M if there is not
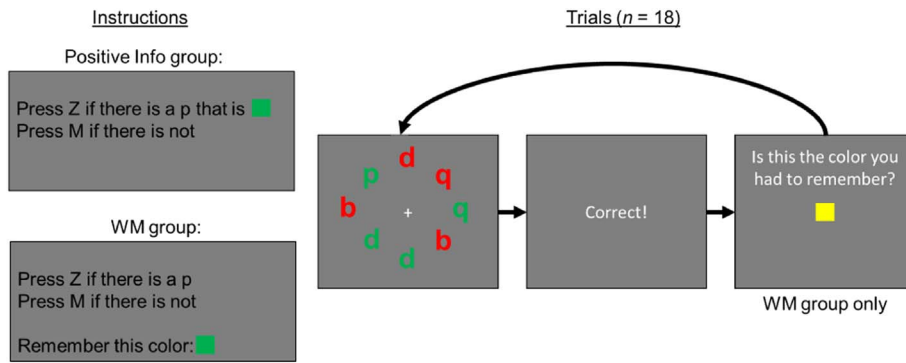
Remember this color: ▮

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

instructed to report whether the target letter is a particular color or not (e.g., is the p green or not). This allows one color to provide "positive information" and the other color to provide "negative information" with respect to the tested proposition (Klayman & Ha, 1987). What we are interested in is whether visual search will exhibit a bias towards positive information; that is, whether search times will depend on the number of matching colors (i.e., the number of green letters, in the example given), as search for color-defined targets can be restricted to color subsets (Egeth, Virzi, & Garbart, 1984; Bacon & Egeth, 1994). Our previous investigations (Rajsic et al., 2015; Rajsic, Taylor, & Pratt, 2016; Rajsic, Wilson, & Pratt, 2017) have shown that a bias towards positive information does win out over the alternative strategy of attending to the smaller color subset (Sobel & Cave, 2002).

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

2. Experiment 1

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

2.1. Methods

2.1.1. Participants

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

2.1.2. Stimuli and procedure

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

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

Instruction displays for the positive information condition consisted of the instruction "Press *a* if the *target* is this color: *color*. Press *b* if it is not." printed in the upper left of the screen. Instruction displays for the working memory condition used the instruction "Press *a* if the *target* is present. Press *b* if it is not." For both instruction types, the keys Z and M were used in a counterbalanced order to stand for responses *a* and *b*, and the *target* letter could be either p, b, d, or q. For the positive information condition, the *color* consisted of a small (1° by 1°) square colored in with the RGB coordinates of the template-matching color used for all subsequent search displays for that instruction. Instruction displays were presented until the participant pressed the Enter key to begin the experiment, with a minimum 1-s duration to ensure the instructions were not skipped by accident.

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

On Target Present trials, one of the letters was the target letter, and the other seven distractor letters were chosen from the three remaining letters, randomly sampled with replacement. On color-matching trials, the target appeared in the color presented during the instructions. On