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**Is attention really biased toward the last target location in visual search?  
Attention, response rules, distractors and eye movements**

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### **Abstract**

The visual search and target-target cueing literatures have reached opposite conclusions about whether a shift of attention is biased toward or away from, respectively, previously attended target locations. This paper figures out why. The main differences between the two experimental approaches concern (1) the stimulus-response translation rules (“what” identification keypresses versus “where” localization responses), (2) the amount of attention required to identify the target, and (3) distractor presence or absence. Experiment 1 tested the role of stimulus-response translation rules by requiring both an eye movement “where” response and a keypress “what” response to each target, in a typical search paradigm. Eye movements showed a bias away from the vicinity of the previous target, whereas keypress showed a bias toward the previous target location, but only when the keypress response repeated. Experiment 2 removed the keypress identification requirement to test whether reducing the amount of attention to the target would alter the eye movement bias; it did not. Experiment 3 removed the distractors to test whether eliminating the potential for distractor-location effects would alter the eye movement bias; it did, by punctuating the eye movement bias against the last target location. Collectively, the findings reveal that different stimulus-response translation rules and distractor processing requirements are the main reasons for the discrepancy while demonstrating that shifts of attention tend intrinsically away from prior target locations. The findings are generally consistent with episodic retrieval and inhibited spatial re-orienting theories.

Is it easier to find a target stimulus when its location repeats within a display? The answer to this simple question has proven surprisingly complicated. Findings from the visual search literature suggest that a target is identified more efficiently when its location repeats (e.g., Maljkovic & Nakayama, 1996; Hilchey, Leber & Pratt, 2018). Findings from the target-target cueing literature, in which a localization response is made first to a cue and then later to a target, suggest that a target is localized less efficiently when its location repeats (e.g., Kwak & Egeth, 1992; Huffman, Hilchey & Pratt, 2018). Both literatures claim that the findings reflect bias in the deployment of attention, either toward the previous target location (visual search) or away from it (cueing). What is responsible for this discrepancy?

Prior literature has identified three likely culprits, the first being a difference in stimulus-response translation rules (Tanaka & Shimojo, 2000). In the search literature, each target is typically associated with a unique keypress response (discrimination tasks), whereas in the cueing literature, each target location is associated with a unique response (localization tasks). This difference is particularly important to episodic retrieval theories (Hommel, 2004; 2007). According to such theories, whenever a response or location repeats, the location or response last associated with it, respectively, is retrieved. If there is a mismatch between the retrieved information and the required information, interference occurs, slowing down responding (Hommel, 1998; Hommel, Proctor & Vu, 2004; Hilchey, Rajsic, Huffman & Pratt, 2017). Thus, interference at this level can affect the discrimination but not the localization responses because with the latter responses, neither repeating nor changing the target location can result in a partial location-response match.

Second, often confounded with the first difference, visual search studies typically require a fine-grained perceptual analysis of each target, whereas cueing studies do not. Indeed, search studies require choice responses to target identity (e.g., shape or color), whereas cueing studies

require choice responses to target location, irrespective of target identity. Accordingly, whether responses to previous target locations are facilitated may depend on the perceptual processing demands at the target location. The claim that the deployment of attention is biased to the previous target location only when a fine-grained perceptual analysis must be performed – and thus focal attention is required – is consistent with this suggestion (e.g., Yashar & Lamy, 2010; Krummenacher et al., 2009; Tanaka & Shimojo, 1996; 2000; Maljkovic & Nakayama, 1996).

Third, search studies, by definition, embed their target in an array of distractors and often the target location either repeats or changes to a distractor location. Typical cueing studies do not include distractors. This difference may be important because presenting a target at a previous distractor location relative to a previously vacant location can slow down responding (e.g., Kumada & Humphreys, 2002; Maljkovic & Nakayama, 1996; Tipper, Brehaut & Driver, 1990). There are multiple interpretations of such findings, but in the rubric of episodic retrieval theories (Neill & Mathis, 1998; Neill, Valdes & Terry, 1995), they have been attributed to a conflict between the prior distractor location's response code (i.e., "do not respond") and the response code that is needed when a target later appears at it.

Here, we test the relative contributions of the three possible factors for differential target location transition effects by starting out with a visual search task that requires a subtle discrimination of the target shape and then modifying it until we are left with a target-target cueing approach that requires neither a fine-grained perceptual analysis of the target shape nor distractor processing. Thus, the factors responsible for faster versus slower responses when the target location repeats relative to when it does not are determined through the progression of the experiments.

## Experiment 1

We adapted the approach from the search literature that uses chipped diamond stimuli to stack the deck in favor of obtaining faster responses for target location repeats than switches (e.g., Maljkovic & Nakayama, 1996). The target color was either red or green, with three distractors taking on the non-target color. Participants indicated the side on which the diamond was chipped by pressing one of two keys, and the target location randomly repeated or switched to a distractor location across displays.

Most importantly, participants were required to make an eye movement from a central fixation point to each target before the keypress. This method thus allows us to assess the eye movement initiation times and keypress response times to test whether the target is localized and identified, respectively, more efficiently when its location repeats in a visual search task that requires the enactment of a fine-grained perceptual analysis of the target.

## Methods

### *Participants*

Seventeen undergraduates from the University of Toronto consented to participate. They received course credit or \$10 cash (CDN). All participants had normal or corrected-to-normal vision.

### *Stimulus and Apparatus*

Eye movements were monitored by an EyeLink 1000 Desktop Mount eye tracker (ST Research, Ottawa, Ontario, Canada) with a temporal threshold of 1000 Hz and spatial resolution of  $0.01^\circ$  of visual angle. The velocity and acceleration thresholds for eye movements were set to  $35.0^\circ/s$  and  $9500.0^\circ/s^2$ . Stimuli were displayed on an 18-inch Dell P992 CRT monitor (Dell Computer, Round Rock, TX) with a refresh rate of 85 Hz and 1,024 x 768 pixels resolution. Head position was stabilized by a chin and headrest 57 cm from the monitor. Standard 9-point

calibration and validation procedures were used until the average measurement error on gaze position was within a half degree. Keypresses were made with the spacebar (right thumb), “B” key (right index finger) or “N” key (right middle finger) on a QWERTY keyboard.

The fixation display consisted of a white fixation cross on a black background, located at screen center and subtending  $0.5^\circ \times 0.5^\circ$ . The cue-back display consisted of a white circle (radius =  $0.25^\circ$ ) at the center of the screen. Each search display consisted of one uniquely colored red or green diamond ( $2.0^\circ \times 2.0^\circ$ ) and three same-colored diamonds in the non-target color. Each diamond was positioned  $9.90^\circ$  away from the fixation cross to form an imaginary square ( $7.0^\circ \times 7.0^\circ$ ) and one corner of each diamond was cut  $0.5^\circ$  inward.

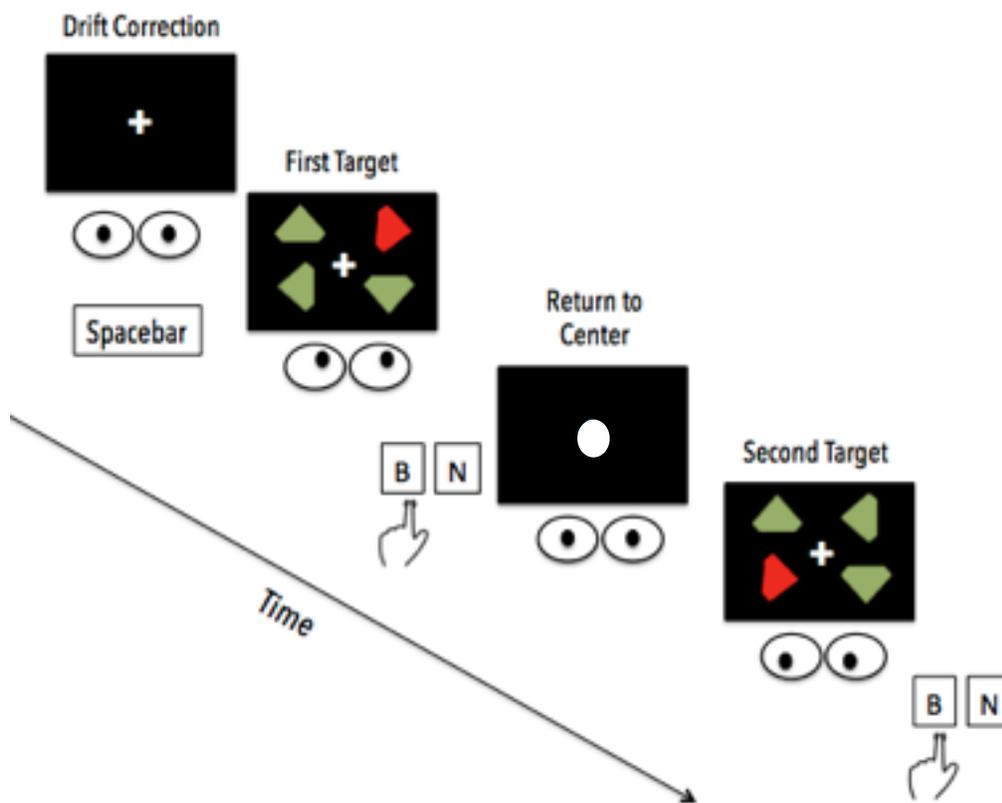
### *Procedure*

The sequence of events is presented in Figure 1. To begin each trial, the participant initiated a drift correction procedure by staring at the fixation cross and pressing the spacebar. Successful and unsuccessful drift corrections were signaled by tones. If successful, a half second later, the first search display appeared.

On the first search display, the participant made an eye movement to the uniquely colored diamond (the “target”). The participant then indicated whether the diamond was chipped on its left or right (‘B’ keypress), or top or bottom (‘N’ keypress). Once the eyes landed within  $3^\circ$  of the target and a keypress was made, the display disappeared and the fixation cross transformed into a white circle, which we refer to as a cue-back because it cues the eyes back to fixation. Once the return eye movement landed within  $3^\circ$  of center, the cue-back transformed into a fixation cross. The participant stared at fixation for 1 second, then the second search display appeared. The task on the second search display was the same as on the first. Once the eyes landed within  $3^\circ$  of the target and the keypress was made, all stimuli disappeared, signaling the end of the trial.

If an incorrect keypress was made, an error message appeared at the end of the trial with a reminder of the correct keypress-response mappings. If eight or more eye movements were made, the trial immediately ended with an error message. Participants had to acknowledge these messages with the spacebar. There was a 1 second blank inter-trial interval.

Participants were told that there was no relationship between successive targets. They were also told that an eye movement was required to each target before the keypress. They were told that each trial could be completed with only three eye movements. Each participant performed 20 practice trials and then 384 experimental trials.



*Figure 1.* A possible trial sequence in Experiment 1. Each target is looked at and then identified with one of two keypresses, after which the eye is re-oriented to screen center. Here, the distance between the two target locations is maximal (i.e., change diagonal), the target color has repeated and so has the manual response.

## Results

### *Exclusions*

One participant was replaced because he made more than eight eye movements on over 25% of trials. Of the remaining data, 7.94% of trials were excluded for more than eight eye movements. 0.4% because the keypress to the target in the second search display occurred before the eye movement; 0.6% because the eyes were not within 5 degrees fixation at the time of the second display; 17.71% because the first eye movement to the second display did not land within 5 degrees of the target (an error that was frequent when the target color switched, see Table 1); 3.61% because a keypress error was made; 0.29% and 0.26% for exceptionally slow eye movements (> 1 second) and keypresses (> 2.5 s), respectively, to the second display. Next, z-scores were computed for each participant for both saccadic and keypress RTs to detect outliers (z-scores > or < 3) on the second display; 1.1% and 1.2% of trials were excluded as outliers, respectively.

### *Saccadic responses*

The mean saccadic response times (SRTs) and error rates are presented in Table 1. The SRTs were analyzed with a 4 (Target Location Transition: same, change vertical, change horizontal, or change diagonal) x 2 (Target Color Repetition: repeat or switch) repeated measures analysis of variance (ANOVA). There was an effect of Target Location Transition,  $F(3, 45) = 4.453$ ,  $p < 0.01$ ,  $\eta_p^2 = 0.2289$ . SRTs were fastest when the distance between the two targets was greatest (i.e., diagonal; see Figure 2, left panel). There was also an effect of Target Color Repetition,  $F(1, 15) = 75.77$ ,  $p < 0.01$ ,  $\eta_p^2 = 0.8347$ . SRTs were faster when the target color repeated (292 ms) than switched (349 ms). There was no interaction,  $F < 1$ . There were no concerns about speed-accuracy tradeoffs, as the error rates tended in the same direction as the SRT data (see Table 1).

*Table 1.* Mean saccadic response times (ms; line 1) and saccade landing error rates (%; 'line 2) in Experiment 1 for all combinations of target color and location transition. Standard deviations are in parentheses.

	Repeat Color	Switch Color
Same Location	293 (100) 8.48 (4.47)	356 (132) 30.47 (13.73)
Change Vertical	296 (97) 10.80 (4.41)	355 (115) 34.10 (19.16)
Change Horizontal	294 (103) 7.90 (4.15)	344 (107) 32.86 (19.49)
Change Diagonal	283 (91) 6.65 (6.22)	341 (116) 26.58 (12.42)

### *Manual responses*

The mean manual response times (MRTs) and error rates are presented in Table 2 and were analyzed with a 4 (Target Location Transition) x 2 (Target Color Repetition) x 2 (Target Response Repetition: repeat or switch) repeated measures ANOVA. The effect of Target Location Transition was marginal,  $F(3, 45) = 2.153$ ,  $p = 0.107$ ,  $\eta_p^2 = 0.1255$ , with MRTs being fastest when the target location repeated (849 ms; 871, 863 and 861 ms for change vertical, horizontal and diagonal, respectively). There was an effect of Target Color Repetition,  $F(3, 45) = 86.26$ ,  $p < 0.01$ ,  $\eta_p^2 = 0.8519$ , with faster keypresses when the target color repeated (806 ms) than switched (916 ms). The effect of Target Response Repetition was not significant ( $F < 1$ ).

Target Location Transition and Target Response Repetition interacted,  $F(3, 45) = 4.874$ ,  $p < 0.01$ ,  $\eta_p^2 = 0.2452$  (see Figure 2, right panel). Repeating the target location and response led to especially fast reactions relative to all other transitions. The only other interaction to approach significance was between Target Color Repetition and Target Response Repetition,  $F(1, 15) = 4.245$ ,  $p = 0.0571$ ,  $\eta_p^2 = 0.2206$ . The effect of repeating the target color was larger when the response repeated (123 ms) than switched (95 ms). No other interactions were significant ( $ps > 0.432$ ,  $\eta_p^2s < 0.0587$ ).

Keypress errors to the second display (% error) were evaluated for speed-accuracy trade-offs with an ANOVA involving the same factors. The effects of Target Location Transition,  $F < 1$ , and Target Color Repetition,  $F(1, 15) = 2.344$ ,  $p = 0.147$ ,  $\eta_p^2 = 0.1351$ , were not significant. The effect of Target Response Repetition was significant,  $F(1, 15) = 6.267$ ,  $p = 0.024$ ,  $\eta_p^2 = 0.2947$ , with more accurate responses for response repeats (2.50%) than switches (4.00%).

There were two two-way interactions. One was between Target Color Repetition and Target Response Repetition,  $F(1, 15) = 23.20$ ,  $p < 0.01$ ,  $\eta_p^2 = 0.4877$ . Generally speaking, more errors were made when the color and response both repeated (3.42%) or switched (6.10%) relative to when only the color (1.91%) or response (1.57%) switched. More critically, the other was between Target Location Transition and Target Response Repetition,  $F(3, 45) = 14.28$ ,  $p < 0.01$ ,  $\eta_p^2 = 0.6074$ : for response repeats, repeating the target location led to more errors (5.01%) than all other location transitions,  $F(3, 45) = 6.23$ ,  $p < 0.01$ ,  $\eta_p^2 = 0.2935$ , with the other location transitions yielding similar error rates ( $F < 1$ ; change vertical = 2.04%; change horizontal = 1.15%; change diagonal = 2.04%). Thus, the especially fast responses for location and response repeats at least partly reflected a speed-accuracy tradeoff. For response switches, repeating the target location led to fewer errors (2.22%) relative to all other location transitions,  $F(3, 45) = 4.604$ ,  $p < 0.01$ ,  $\eta_p^2 = 0.2348$ , with the other transitions yielding roughly similar error rates ( $F(2, 30) = 2.76$ ,  $p = 0.080$ ,  $\eta_p^2 = 0.1552$ ; change vertical = 3.81 %; change horizontal = 5.91%; change diagonal = 4.06%). The remaining interactions were not significant,  $F_s < 1$ .

*Table 2.* Mean manual response times (ms; line 1) and manual error rates (%; line 2) in Experiment 1 for all combinations of target color, target location transition and response repetition. Standard deviations are in parentheses.

	Repeat Response		Switch Response	
	Repeat Color	Switch Color	Repeat Color	Switch Color
Same Location	770 (234) 5.76 (6.53)	884 (236) 4.26 (6.56)	817 (207) 1.14 (2.46)	947 (272) 3.35 (4.88)
Change Vertical	800 (229) 2.49 (4.54)	955 (237) 1.59 (3.71)	835 (233) 1.00 (2.23)	939 (257) 6.64 (8.84)
Change Horizontal	802 (227) 2.30 (4.67)	943 (255) 0.00 (0.00)	823 (233) 3.52 (4.30)	900 (241) 8.30 (6.93)
Change Diagonal	798 (233) 3.15 (4.52)	933 (245) 0.42 (1.67)	784 (208) 2.01 (3.24)	914 (272) 6.11 (6.14)

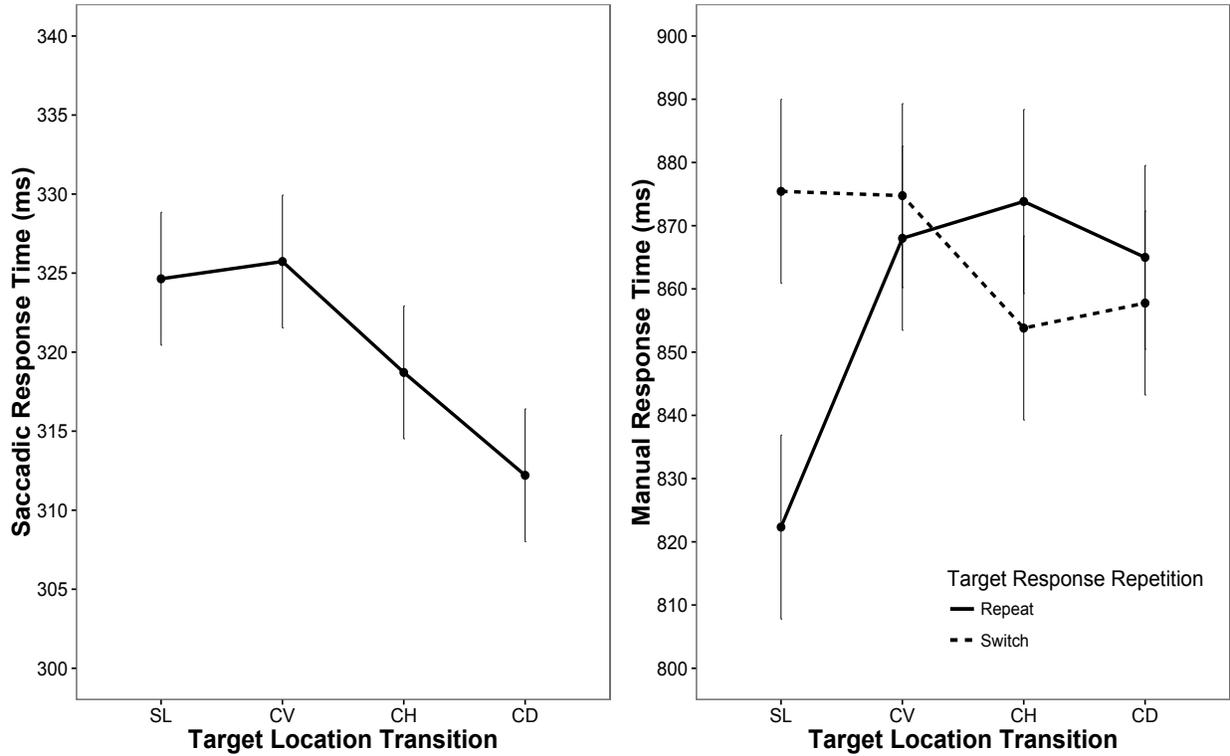


Figure 2, left panel. The effects of target location transitions on eye movement response times in Experiment 1. Right panel. The interaction between target location transition and response repetition on keypress discrimination response times. Errors bars are protected half Fisher Least Significant Differences (FLSDs) computed from the mean squared error term of the effect and interaction, respectively; overlap signifies a non-significant simple effect. SL = same location; CV = change vertical; CH = change horizontal; CD = change diagonal.

## Discussion

Turning first to the MRTs, we achieved our goal of creating a situation where responses were faster for targets at repeated locations. Importantly, this was qualified by an interaction with response repetition, such that faster responses only occurred when both the target location and the response repeated. This is consistent with recent findings showing that post-attentional orienting processes factor into the keypress identification responses (e.g., Hilchey, Leber & Pratt, 2018; Hilchey, Rajsic, et al., 2018; Gokce, Geyer, Finke, Muller & Tollner, 2014), as suggested by episodic retrieval theories postulating interference whenever (1) a target appears at a prior distractor location (Neill & Mathis, 1998), (2) a target location repeats but the response changes, or (3) the response repeats but the target location changes (Hommel, 2004).

Accordingly, the only location transition not suffering from some amount of interference would be target location and response repeat, as found here. However, interestingly and unexpectedly, the error rate analysis suggested a speed-accuracy tradeoff. To account for this tradeoff, retrieval theories must assume that at least some forms of interference can delay decision-making processes without affecting the quality of the visual signals or stimulus-response translation.

With the MRTs being an unreliable indicator of whether attention is biased away or toward repeated locations, we turn to the SRTs. Here the data were quite clear; SRTs were never any faster when the target location repeated instead of switched and were indeed slower when the target location/hemifield repeated relative to the change diagonal transition. Thus, not even in a visual search situation that requires a fine-grained perceptual analysis of the target is there evidence that targets are located more quickly when their location repeats. Instead, the SRT data revealed a weak bias against the last target location/hemifield, generally consistent with the idea that a shift of attention is biased against the vicinity of a prior target (Vaughan, 1984; Klein & Redden, 2018).

As a secondary point, the MRTs and SRTs reveal bias toward the last target color, consistent with other research (e.g., Moher & Song, 2016).

## **Experiment 2**

An unusual effect in the SRTs of Experiment 1 was that they were equally slow irrespective of whether the target location or hemifield repeated. Why weren't responses especially slow when the target location repeated, as shown by previous eye movement research in target-target cueing paradigms (e.g., Jayaraman et al., 2016)? It could still be the case that performing a fine-grained perceptual analysis of the target required focal attention, which produced some amount of facilitation at the prior target location that added with any inhibition that was generated by orienting to it, as suggested by Maljkovic and Nakayama (1996). To test this possibility, we replicated Experiment 1 but eliminated the need to discriminate the target's shape once looked at. If this kind of focal attention biased subsequent shifts of attention toward the last target location, thus offsetting some of the inhibition at it, then by removing this focal attention requirement, we should be able to show that SRTs become especially slow when the target location repeats.

## **Methods**

### *Participants*

Sixteen different undergraduates at the University of Toronto consented to participate for course credit or cash. All had normal or corrected to normal vision.

### *Apparatus, Stimuli and Procedure*

These were similar to Experiment 1, with two exceptions: (1) keypress responses to targets were no longer required, and (2) participants were required to maintain their eyes at the target location for 500 or 700 ms before the search array disappeared, which ensured similar exposure durations for the search displays between experiments.

## Results

We excluded 8.45% of trials for more than 8 eye movements; 0.20% because the eyes were not within 5 degrees of fixation at the time of the second search display; 11.90% because the first eye movement to the second search display did not land within 5 degrees of the target and 1.1% were lost to SRT outliers.

The SRTs appear in Table 3 and were analyzed with a 4 (Target Location Transition) x 2 (Target Color Repetition) repeated measures ANOVA. There was an effect of Target Location Transition,  $F(3,45) = 4.854$ ,  $p < 0.01$ ,  $\eta_p^2 = 0.2445$ . SRTs were fastest when the separation between the two targets was greatest (see Figure 3). There was an effect of Target Color Repetition  $F(1,15) = 196.00$ ,  $p < 0.01$ ,  $\eta_p^2 = 0.9289$ , with faster SRTs when the target color repeated (268 ms) instead of changed (302 ms). The interaction was not significant  $F < 1$ . There were no concerns for speed-accuracy tradeoffs.

### *Comparison between Experiments 2 and 1*

To directly assess whether orienting was affected by the requirement to discriminate the target's shape, we conducted the same ANOVA on SRTs except that we included Experiment as a between-subject factor. There was no effect of Experiment,  $F(1, 30) = 1.348$ ,  $p = 0.255$ ,  $\eta_p^2 = 0.0430$ , no interaction between Target Location Transition and Experiment,  $F(3, 90) = 1.023$ ,  $p = 0.386$ ,  $\eta_p^2 = 0.0330$ , and no three-way interaction,  $F < 1$ . However, there was an interaction between Experiment and Target Color Repetition,  $F(1, 30) = 11.04$ ,  $p < 0.01$ ,  $\eta_p^2 = 0.2689$ .

Repeating the target color sped up SRTs more in Experiment 1 (57 ms) than 2 (34 ms), with the former requiring discrimination of the target shape.

*Table 3.* Mean saccadic response times (ms; line 1) and saccadic landing error rates (%; line 2) in Experiment 2 for all combinations of target color and location transitions. Standard deviations are in parentheses.

	Repeat Color	Switch Color
Same Location	268 (57) 6.48 (7.91)	303 (59) 20.85 (12.40)
Change Vertical	274 (62) 7.32 (8.57)	305 (58) 23.24 (12.76)
Change Horizontal	268 (57) 6.63 (5.72)	302 (58) 21.47 (12.25)
Change Diagonal	262 (49) 4.00 (3.62)	298 (60) 17.34 (12.46)

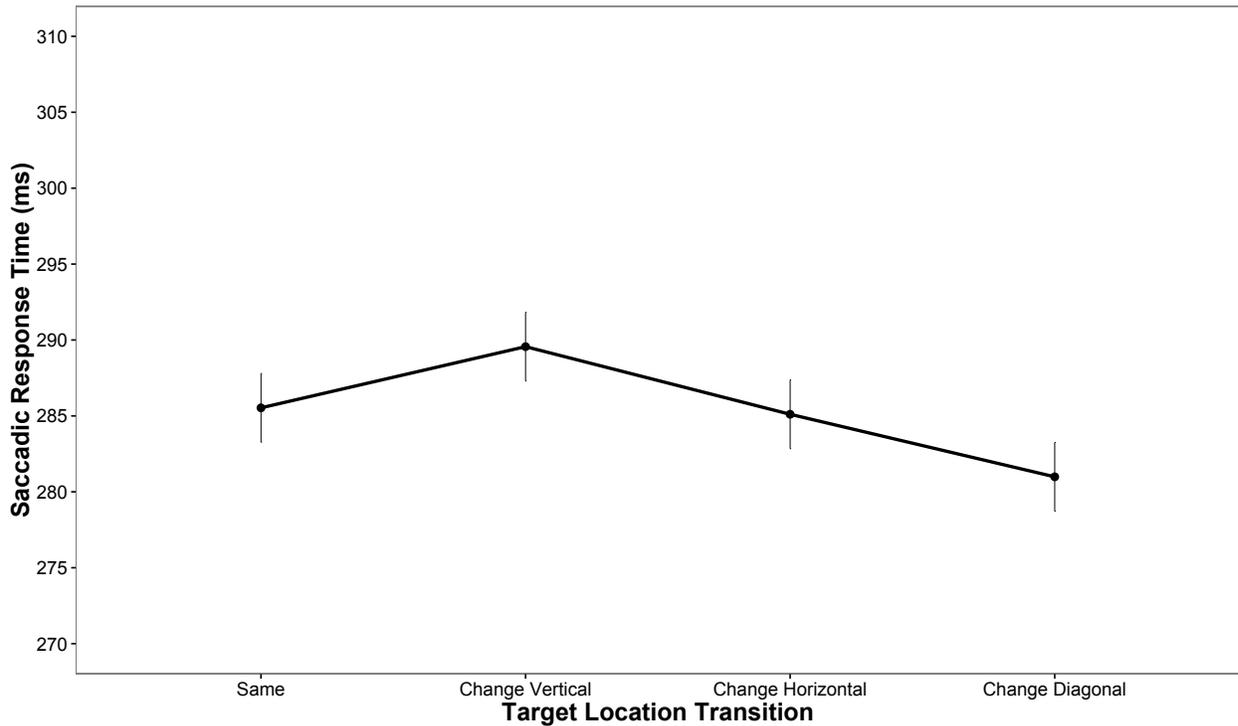


Figure 3. The effects of target location transitions on eye movements in Experiment 2. Errors bars are protected half Fisher Least Significant Differences (FLSDs) computed from the mean squared error term of the effect; overlap signifies a non-significant simple effect.

### Discussion

Once again, SRTs were slowest when the target hemifield repeated. Thus, the requirement to perform a fine-grained perceptual analysis of the target shape after the shift in gaze did not determine target location transition effects. As a secondary point, this focal attention requirement did amplify the tendency to look for its color in the next search display.

### Experiment 3

Because taking away the shape discrimination did not restore the typical SRT pattern, we now turn to the role of distractors. Specifically, maybe partial overlap between a distractor location's response code and a target location's response code led to some amount of interference, as would occur when a target appeared at a prior distractor location. Any such interference would help offset any inhibition at the target location caused by shifting attention to it. This possibility is evaluated by removing the distractors. If there was a gradient of inhibition at the prior target location plus interference whenever a target appeared at a prior distractor location in the earlier experiments, removing the distractors should be sufficient for eliminating that interference, thereby revealing especially slow SRTs whenever the target location repeats.

### Methods

#### *Participants*

Sixteen different undergraduates at the University of Toronto consented to participate for course credit or cash. All had normal or corrected to normal vision.

#### *Apparatus, Stimuli and Procedure*

These were similar to Experiment 2, except that target displays no longer contained distractors.

### Results

We excluded 5.94% of trials for more than 8 eye movements; 1.66% because the eyes were not within 5 degrees of fixation at the time of the second target display; 2.77% because the first eye movement to the second target did not land within 5 degrees; 0.02% of trials for exceptionally slow ( $>1$  s) and anticipatory ( $< 80$  ms) eye movements to the second target display. 1.2% of trials were lost to SRT outliers.

Mean SRTs appear in Table 4 and were analyzed with a 4 (Target Location Transition) x 2 (Target Color Repetition) repeated measures ANOVA. There was an effect of Target Location Transition,  $F(3, 45) = 10.86$ ,  $p < 0.01$ ,  $\eta_p^2 = 0.4200$ . SRTs were especially slow when the target location repeated relative to other transitions, with the change vertical transition falling somewhere in between (see Figure 4). This was not a speed-accuracy tradeoff (see Table 4). There was no effect of Target Color Repetition and no interaction,  $F_s < 1$ .

#### *Comparison between Experiments 3 and 2*

To directly assess whether orienting was influenced by distractor presence, we conducted the same ANOVA on SRTs except that we included Experiment (Experiment 2, distractors versus Experiment 3, no distractors) as a between-subject factor. The effect of Experiment was significant,  $F(1,30) = 26.36$ ,  $p < 0.01$ ,  $\eta_p^2 = 0.4677$ , with faster SRTs in Experiment 3 (198 ms) than 2 (285 ms). More importantly, there was an interaction between Target Location Transition and Experiment,  $F(3, 90) = 5.527$ ,  $p < 0.01$ ,  $\eta_p^2 = 0.1556$ ). In Experiment 2, SRTs were especially slow when the target hemifield repeated relative to the change diagonal condition (Figure 3). In Experiment 3, SRTs were especially slow whenever the target location repeated (Figure 4).

There was also an interaction between Experiment and Target Color Repetition,  $F(1, 30) = 138.70$ ,  $p < 0.01$ ,  $\eta_p^2 = 0.8221$ . Target Color Repetition had no apparent effect on SRTs in Experiment 3 (1 ms), whereas it speeded SRTs in Experiment 2 (34 ms). The three-way interaction was not significant,  $F < 1$ .

*Table 4.* Mean saccadic response times (ms; line 1) and saccadic landing errors (%; line 2) in Experiment 3 for all combinations of target color and location repetition. Standard deviations are in parentheses.

	Repeat Color	Switch Color
Same Location	205 (57.59) 3.40 (2.76)	206 (60.86) 3.13 (3.41)
Change Vertical	198 (61.50) 3.67 (4.53)	198 (60.94) 2.05 (2.32)
Change Horizontal	192 (60.50) 3.76 (3.35)	195 (60.25) 2.73 (3.91)
Change Diagonal	195 (59.09) 2.67 (3.66)	196 (57.90) 2.88 (2.82)

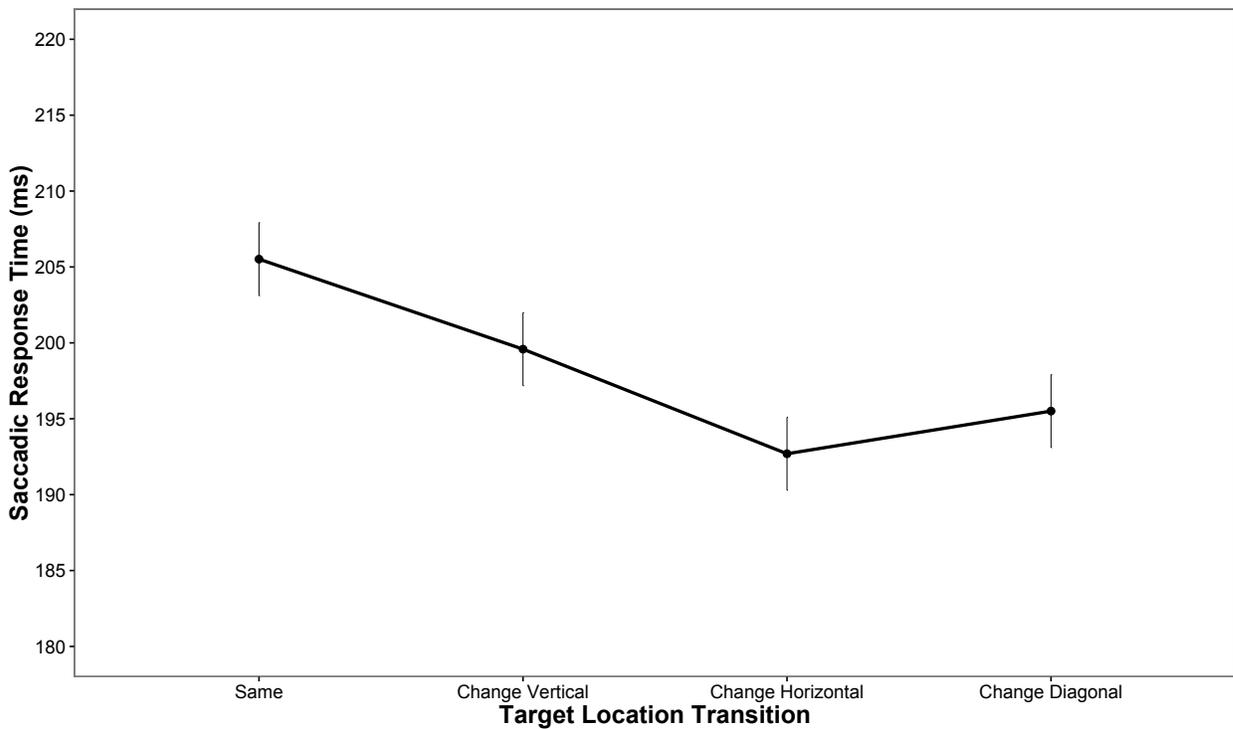


Figure 4. The effect of repeating the target location on eye movements in Experiment 3. Errors bars are half Fisher Least Significant Differences (FLSDs) computed from the mean squared error term of the effect; overlap signifies a non-significant simple effect.

### Discussion

Distractor removal, and thus returning to the target-target cueing paradigm, restored the typical target location transition effects. The slowest SRTs occurred specifically when the target location repeated. The findings suggest that there was a cost associated with presenting a target

at a prior distractor location, which is consistent with episodic retrieval theories.<sup>1</sup> Theoretically, if this cost could be made larger than the bias against the last target location, there would be a net bias in favor of the last target location. As a secondary point, the previously observed advantage for repeating the target color vanished, as expected given that paying attention to color was no longer necessary to find the target (e.g., Goolsby & Suzuki, 2001; Huffman et al., 2018).

### General Discussion

How is it that two literatures (visual search, target-target cueing), using very similar paradigms, have arrived at opposite conclusions about whether attention is facilitated or inhibited to prior target locations? Having identified three differences between these literatures – the stimulus-response translation rules, the requirement to perform a fine-grained perceptual analysis of the target, and distractor presence – we systematically tested them across three experiments.

The first experiment showed that target location transition effects were different depending on the stimulus-response translation rules. SRTs were slower when the target location/hemifield repeated instead of switched to the mirror opposite target location, a result consistent with shifts of attention being biased against the vicinity of an earlier target. Contrasting with these findings, MRTs were generally faster when the target location repeated, but only when the response also repeated, a result consistent with episodic retrieval theories, which posit interference whenever this is a partial mismatch between a current and prior stimulus

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<sup>1</sup> We thank an anonymous reviewer for suggesting an alternative interpretation. The difference between experiments could be at least partly explained by an asymmetry in the amount of perceptual analysis that was required before the target could be localized. In Experiment 3, it was not necessary to distinguish the target from the distractor colors in order to produce the correct eye movement. In Experiment 2, it was. Accordingly, the comparison between Experiments 2 and 3 could be taken to suggest that the requirement to perceptually analyze a target *before* it is localized behaviorally, but not *after* (cf. Experiments 1 and 2), is a determinant of the location transition effects. Taking this a step further, hypothetically, if the target were even more difficult to distinguish from the distractors, any eye movement bias toward the last target location could be enhanced to outweigh the bias against it.

location and response. Accordingly, the only location transition not suffering from some amount of proactive interference would be target location and response repeat.

Whether a fine-grained perceptual analysis of the target was needed to make a keypress (Experiment 1) or not (Experiment 2) did not alter the eye movement bias against the vicinity of the last target. Whether there were distractors (Experiment 2) or not (Experiment 3) did alter this eye movement bias. With distractors (Experiment 2), eye movements were slowest whenever the target hemifield repeated, regardless of whether the target location repeated. Without distractors, eye movements were slowest specifically when the target location repeated. There was a cost associated with there being a target at the prior distractor location, consistent with episodic retrieval theories postulating proactive interference between a past “do not respond” distractor location code and a required target location response code.

Collectively, the SRT data are consistent with research showing slower eye movements when the target location repeats instead of switches to a more distant location, which is observed with distractors (e.g., Bichot & Schall, 2002; Tanaka & Shimojo, 1996), without distractors (Hilchey, Rajsic, et al., 2018; Vaughan, 1984) and, as also shown here, regardless of whether a fine-grained perceptual analysis of the target is needed, once looked at. There is simply no direct evidence that eye movements, which we have evaluated for orienting bias, are biased overall in favor of the prior target location in simple visual search. Ultimately, the discrepancy between literatures results from a combination of different stimulus-response rules and distractors. The SRT and MRT target location transition data in this paper are consistent with a combination of episodic retrieval and inhibited spatial re-orienting theories. Any link between performing a fine-grained perceptual analysis (i.e., focal attention) and biased re-orienting to the last target location in visual search is either wrong or not yet necessitated by the data.

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