Covert Attention is Attracted to Prior Target Locations: Evidence from the Probe Paradigm

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Abstract

There is growing evidence that visual attention can be guided by selection history. One example of this is intertrial location priming, whereby attention is attracted to the target location from the previous trial. Most previous demonstrations of location priming have relied on manual response time effects whereby search is speeded when the target location repeats from the previous trial. However, these latency-based effects have recently been challenged as being due to response facilitation that occurs after the target has been found, rather than an attentional bias toward the previous target location. To resolve this, the current study used a probe paradigm to assess whether covert attention is biased to the previous-trial target location. On search trials, participants searched for a specific target shape amongst distractor shapes and made a speeded response to the location of a dot inside the target. On probe trials, letters briefly appeared at each search location and after a delay, participants were asked to report as many letters as possible. Probe report accuracy was used to assess the likelihood that a given location was attended. Three experiments indicated that probe report accuracy was greatly improved for letters at the previous-trial target location compared to baseline levels. Importantly, this occurred even when strong attentional guidance to the target was encouraged and even when a nontarget stimulus appeared at the primed location. Altogether, the results suggest that covert attention is strongly attracted to the previous target location during visual search.

Keywords: visual attention, selection history, intertrial priming, location priming

Evidence of Intertrial Location Priming in the Capture-Probe Paradigm

Whether we are looking for car keys on a messy table or casually scanning our surroundings when walking through a park, visual attention is crucial for everyday goal-directed behavior. Traditionally, visual attention has been presumed to be guided by explicit goals (Wolfe, 1994). That is, observers can constrain visual attention to search items that match known features of the search target (Wolfe & Horowitz, 2004; Maunsell & Treue, 2006). For example, if someone is searching for lost car keys, they might purposefully constrain visual attention to objects that are small and silver. Typically, it is assumed that visual attention is guided by an attentional template that is maintained in working memory (Carlisle et al., 2011; Woodman & Luck, 2007) and that this template can enhance the gain on simple feature values, such as shape and color.

There is now increasing evidence, however, that visual attention is also guided by recent experience, called *selection history* (Awh et al., 2012; Kristjansson, 2008). The term "selection history" refers to a broad class of associative memory mechanisms that seem to guide visual attention, including statistical learning (Geng & Behrmann, 2002), contextual cueing (Chun & Jiang, 1998), reward history (Anderson, 2016; Anderson et al., 2011), and intertrial priming (Kristjánsson & Ásgeirsson, 2019; Maljkovic & Nakayama, 1994, 1996). As a result, many models of visual attention now include some form of guidance by selection history (Luck et al., 2020; Wolfe, 2021; Wolfe & Horowitz, 2017). One form of guidance by selection history that is of interest to the current study is *intertrial location priming* which is a phenomenon whereby the target location from the previous trial is purported to attract attention on the current trial (Maljkovic & Nakayama, 1996; Walthew & Gilchrist, 2006).

Intertrial Location Priming: Attentional or Post-Perceptual?

Initial evidence of intertrial location priming was demonstrated in the priming-of-popout paradigm. In a seminal study, Maljkovic and Nakayama (1996) had participants search displays of diamonds for a uniquely colored shape and report which side was missing (left or right) via speeded buttonpress. Crucially, the target location was randomly selected on each trial and participants therefore had no incentive to attend the previous-trial target location. Nonetheless, RTs were much faster when the target location was repeated from the previous trial (*repeat-location trial*) than when the target location was changed from the previous trial (*change-location trial*). These results were taken to suggest that attention was attracted to the previous-trial target location, speeding target detection when it appeared at this location. According to *intertrial location priming accounts,* the previous target location is boosted in attentional priority and this causes covert attention to be attracted to the previous target location (Brinkhuis et al., 2020; Kristjánsson et al., 2007; Maljkovic & Nakayama, 1996).

This RT-based location priming effect has now been replicated across various experimental paradigms (Geyer et al., 2007; Geyer & Müller, 2009; Sauter et al., 2018; Tanaka & Shimojo, 1996, 2000; Terry et al., 1994; Tower-Richardi et al., 2016). Further evidence of location priming has come from studies demonstrating that saccadic eye movements are attracted to the previous-trial target location during search (Bansal et al., 2021; Talcott & Gaspelin, 2020; Walthew & Gilchrist, 2006). Additionally, some fMRI studies have shown repeating the target location in a priming-of-popout paradigm modulates BOLD activity in areas implicated in the control of visual attention (Brinkhuis et al., 2020; Geng et al., 2006; Kristjánsson et al., 2007).

It has been suggested, however, that location priming may not actually influence attentional allocation. Rather, location priming—and other forms of intertrial priming—may merely influence cognitive processes that occur *after* attentional allocation, such as manual response selection (Campana & Casco, 2009; Hilchey, Rajsic, et al., 2018; Hillstrom, 2000; Huang et al., 2004; Lamy et al., 2010; Ramgir & Lamy, 2021). According to these *post-perceptual accounts* of intertrial priming, manual responses are speeded when the target location or target features are repeated from the previous trial. In terms of location priming, this means that manual RT will be speeded on repeat-location trials compared to change-location trials due to a faster response selection stage. In other words, target items with repeated locations may be quickly recognized and responded to, even though attention is not initially biased toward these items.

Some compelling evidence that location priming can influence cognitive stages after attentional allocation has come from studies of eye movements in priming-of-popout paradigms (Hilchey et al., 2019; Hilchey, Leber, et al., 2018; Hilchey, Rajsic, et al., 2018). For example, Hilchey et al. (2019) had participants perform the same priming-of-popout task as Maljkovic and Nakayama (1996), but required participants to generate a saccade directly to the target before responding. The results demonstrated that manual responses were faster on repeat-location trials than change-location trials, especially when the target response was repeated from the previous trial. Critically, saccadic latencies to the target were slower on repeat-location trials than change-location trials. In other words, participants took *longer* to reorient the eyes to the previous-trial target location; but once they reached this location, responses to the target were facilitated. These results were taken to suggest that attentional allocation to the previous-trial target location was *inhibited* and that previously reported location priming effects may instead reflect priming of manual responses, rather than an attentional bias. This response interference account directly refutes a location priming account because it proposes that covert attentional allocation to the previous-trial target location is suppressed, not facilitated.

In summary, there is an abundance of evidence that intertrial location priming can influence manual RTs in visual search tasks (Geyer & Müller, 2009; Maljkovic & Nakayama, 1996; Tanaka & Shimojo, 1996, 2000). However, it has been questioned whether such results are due to an underlying bias of covert attention toward the previous-trial target location or instead are due to post-perceptual processes that occur after the target stimulus is found.

Preliminary Evidence that Location Priming Influences Covert Attention

Ásgeirsson et al. (2014) provided some evidence that intertrial location priming influences covert attentional allocation. Participants searched for a color popout letter amongst distractor letters of another color and made untimed responses to indicate the identity of the target letter. The stimulus displays were only briefly presented for 10 to 180 ms before being masked. Importantly, report accuracy of the target letter was greater on repeat-location trials compared to change-location trials. This directly suggests that perceptual processing of the target item at the previous-trial target location was enhanced. Critically, this enhancement cannot be explained as a post-perceptual effect because an untimed accuracy task was used with a brief probe presentation duration to keep accuracy below ceiling. As a result, accuracy under these conditions is sensitive to early perceptual processing but is largely insensitive to later post-perceptual processes (e.g., see Kim & Cave, 1995; Santee & Egeth, 1982).

The Ásgeirsson et al. (2014) study is important because it suggests that location priming can truly influence covert attentional allocation, at least under certain circumstances. However, this study leaves two significant questions unresolved. First, the location priming manipulation occurred simultaneously with a feature priming manipulation. That is, participants were required to look for a target defined as a popout item and its specific color was unknown at the outset of the trial. Thus participants had to search for the target based upon its physical salience (Bacon &

Egeth, 1994) and it is therefore unclear whether intertrial location priming can also influence covert attention when explicit goals can be used to locate the target. Second, the probe task only measured accuracy at reporting the target letter. As a result, it is unclear whether location priming is powerful enough to attract attention to a nontarget location.

The Current Study

The present study will assess whether location priming influences covert attentional allocation using a modified *capture-probe paradigm* (Gaspelin et al., 2015). This paradigm has been used extensively to study attentional capture by physically salient stimuli (e.g., Chang & Egeth, 2019; Feldmann-Wüstefeld et al., 2020; Gaspelin et al., 2015; Gaspelin & Luck, 2018a, 2018b) and can easily be adapted to study intertrial priming. The basic approach involves randomly intermixing frequent search trials with infrequent probe trials (Figure 1A). On search trials, participants search for a target shape amongst distractor shapes and make a speeded buttonpress indicating the location of a black dot inside (left or right). The location of the target is selected at random, so there should be no incentive to attend the previous target location. On probe trials, letters are briefly superimposed onto each shape and after a short delay, participants attempt to recall as many letters as possible. Probe report accuracy provides an estimate of covert processing resources at each location in the search display. If intertrial location priming influences covert attentional allocation, probe report accuracy should be enhanced for the letter at the primed location compared to the baseline level of the nonprimed locations.

Importantly, the current study will address the two aforementioned shortcomings of the Ásgeirsson et al. (2014) study. First, the target will be clearly defined by shape (e.g., gray diamond) which should allow participants to develop a strong top-down attentional set for that item. This allows us to test whether location priming can overpower strong goal-driven guidance toward the target stimulus. Second, the capture-probe paradigm allows us to assess whether intertrial priming is powerful enough to guide visual attention to a distractor item, rather than merely improving attentional allocation to the target stimulus.

As previously discussed, several studies have indicated that eye movements are strongly influenced by intertrial location priming (Bansal et al., 2021; Talcott & Gaspelin, 2020; Walthew & Gilchrist, 2006). Such eye movements are problematic for the current study because they could create enhancement effects on probe report that are similar to those due to shifts of covert attention. Therefore, an additional component of the current paradigm is that eye movements were prohibited. In all experiments, eye movements were monitored via eye tracking and discarded at analysis. Additionally, Experiments 2 and 3 use probe stimulus timings that are too brief (100 ms) to allow saccades to search items.

Experiment 1

Experiment 1 adapted the capture-probe paradigm to examine whether location priming can influence covert attentional allocation (Figure 1A). Participants performed a visual search task that has been previously shown to produce strong location priming effects on saccadic eye movements (Talcott & Gaspelin, 2020). Importantly, the target location was selected at random, which resulted in two types of trials (Figure 1B). On repeat-location trials, the target location was the same on trial n as on trial $n - 1$. Thus, on these trials, the target was primed by the previous target location and the remaining items were nonprimed distractors. On change-location trials, the target location on trial n was different than the target location on trial $n - 1$. Thus, on these trials, a distractor was primed by the previous target location (*primed distractor*) and the remaining four distractor items were not primed (*nonprimed distractors*).

Figure 2 depicts competing predictions of performance on the probe task. According to an *intertrial location priming account* (Figure 2A), the previous-trial target location should attract covert attention (Ásgeirsson et al., 2014; Maljkovic & Nakayama, 1996; Talcott & Gaspelin, 2020). This should produce two key patterns of results. First, probe report accuracy for letters at the target location should be higher on repeat-location trials than change-location trials (a *target repetition effect*). Second, on change-location trials, probe report accuracy should be higher at the primed distractor location than the average nonprimed distractor location (a *location priming effect*). In other words, the average of the nonprimed distractors will be used as a baseline for comparison with the primed distractor. To our knowledge, this second comparison has never been assessed.

According to an *intertrial location suppression account* (Figure 2B), the previous target location should be inhibited (Hilchey et al., 2019; Hilchey, Rajsic, et al., 2018). This should yield two patterns of results. First, probe report accuracy for the target location should be lower on repeat-location trials than change-location trials. This is because attention should be reluctant to return to the previous-trial target location, even when the current-trial target occupies that location. Second, on change-location trials, probe report accuracy should be lower at the primed distractor location than the average nonprimed distractor location. Because the capture-probe paradigm was developed to detect the suppression of covert attentional allocation to highly salient items, it should be well-suited to detect these kinds of inhibitory effects (Gaspelin et al., 2015).

According to a *no intertrial priming account* (Figure 2C), the previous target location should neither attract nor repel attention. Instead, intertrial location priming should only affect response stages after the target stimulus is located. Thus, probe report accuracy for the letter at the target location should be approximately equivalent on repeat-location and change-location trials. Additionally, on change-location trials, probe report accuracy should be equivalent at the primed distractor and the average nonprimed distractor locations.

Method

Participants

An a priori sample size of 24 was determined based on previous studies. Assuming that location priming effects in the probe task are similar in magnitude to location priming effects of saccadic eye movements ($d_z = 2.08$ in Talcott & Gaspelin, 2020), this should yield .999 power to detect a significant effect. Ultimately, the magnitude of the location priming effect on probe report was unknown at the outset of this study. As will be seen, we find powerful effects of location priming and we replicate these effects in two experiments.

Participants were undergraduate students at the State University of New York at Binghamton who received course credit for volunteering. Three participants were replaced for making eye movements on more than 25% of trials. One participant was replaced for having abnormally low accuracy (3 SDs less than the group mean of 97.8%). Of the final sample, 15 were women and 9 were men with a mean age of 20.1 years. All participants had normal or corrected-to-normal visual acuity.

Apparatus

Stimuli were presented using PsychToolbox (Brainard, 1997) for Matlab on an Asus VG245 LCD monitor at a viewing distance of 100 cm. A photosensor was used to measure the timing delay of the video system (12 ms) and this delay was subtracted from all latency values in the current study. An SR Research Eyelink 1000+ desk-mounted system recorded the eye position of the right eye at 500 Hz. The Eyelink Toolbox was used to interface the eye tracking system with the stimulus presentation system (Cornelissen et al., 2002).

Stimuli & Procedure

The capture-probe task is depicted in Figure 1A. Search displays consisted of six gray shapes (38.8 cd/m^2, $x = 0.31$, $y = 0.33$) that were presented equidistant from the center of the screen (3° in radius). Each display contained a circle (1.5° in diameter), a diamond (1.7° by 1.7°), a hexagon (1.6° in width by 1.4° in height), a cross (1.5° by 1.5°), a pentagon (1.6° in width by 1.5° in height), and an octagon (1.5° by 1.5°). The location of each shape was randomly varied on each trial. Each shape contained a small black dot (0.2° by 0.2°) that was located on the left or right side. A gray fixation cross (0.7° in diameter) appeared at the center of the screen and was designed to reduce eye movements (Thaler et al., 2013). All stimuli were presented on a black background.

Participants were assigned a target shape (circle or diamond) which remained constant for the entire experimental session and was counterbalanced across participants. The location of the target was selected at random, meaning that repeat-location trials would occur on 1/6th of trials with the current set size of six items. The location of the dot inside the target was selected at random on each trial. Additionally, the locations of the distractor shapes and the locations of the dots inside the distractors were selected at random on each trial.

On search trials (70% of trials), each trial began with a fixation display that consisted of the gray fixation cross alone. To initiate a trial, participants were required to maintain fixation for 500 ms within 1.5° of the center of the display. Next, participants searched for the target shape (e.g., diamond) and reported the location of the black dot inside (left vs. right) using a computer mouse (by clicking the left or right button, respectively). Participants were instructed to locate the target as quickly as possible. They were also told that the target location from the previous trial would not predict the target location on the current trial. If participants did not respond within 2000 ms, a low beep (200 Hz) sounded and the screen displayed the message "Too Slow!" for 300 ms. If the participant made an incorrect response, a 200-Hz tone sounded for 300 ms.

On probe trials (30% of trials), participants first were required to maintain central fixation to initiate the trial (same procedure as search trials). Next, the search array appeared alone for 100 ms. Then, letters were superimposed over each shape in the search display for 200 ms. The letters were six letters from the English alphabet that were randomly selected without replacement. Letters were white in Arial typeface (1.25° height). Next, letters were replaced with a pattern mask (#) for 500 ms. Finally, the response screen appeared which consisted of the full English alphabet in white. Participants then used the computer mouse to select letters they recalled from the probe display. Participants could select anywhere between zero and six letters. When a letter was selected, it turned yellow. When finished, participants clicked a gray "OK" box to submit their response and continue. Probe report was untimed, and participants received no direct feedback on the accuracy of probe report.

Importantly, both search trials and probe trials strictly prohibited eye movements. That is, participants were required to maintain fixation for the duration of the stimulus displays. If gaze position exceeded 1.5° from the center of the screen during a trial, participants were warned after the completion of that trial that they had generated an eye movement and that trial was marked as containing an eye movement. An immediate feedback screen displayed the message "Moved Eyes!" for 600 ms while two 250-Hz tones chirped for 300 ms total (each tone was 100 ms and had 100 ms ISI between tones). The only exception to this is that participants were allowed to generate eye movements during the probe response display, which would be exceptionally difficult if eye movements were prohibited. The 1.5° fixation requirement should prevent eye movements to the search items, which were 3° from fixation (see also Experiments 2 and 3, which reduced the probe duration to further prevent saccadic eye movements).

Each participant first completed two practice blocks of 48 trials containing only search trials. Then, participants completed two practice blocks of 48 trials with randomly intermixed search trials and probe trials. The main experiment consisted of eight blocks of 48 trials. This yielded 384 trials excluding practice block trials (approximately 115 probe trials and 269 search trials). The designation of each trial as either a probe trial or search trial was chosen at random. Of the probe trials, an average of 18.6 trials (*SD* = 4.6) were repeat-location trials and 96.6 trials (*SD* = 9.5) were change-location trials. Before each block, the eye tracking system was calibrated using a five-point calibration procedure. If participants were unable to fixate on the fixation cross at the beginning of the trial within 5000 ms the eye-tracking system was recalibrated. At the end of each block, participants received feedback on search performance for the block (mean RT and mean accuracy for that block).

Data Analysis

The data from practice blocks were excluded from analysis. Additionally, the first trial of each experimental block was excluded from analysis because any intertrial priming would be disrupted by the block break. Trials were also excluded if an eye movement was detected during the presentation of search or probe stimuli (8.9% of all trials). Search trials with an abnormal RT (less than 200 ms or greater than 2.5 SDs from each subject's mean) were also excluded (3.1% of search trials). Additionally, search trials with an inaccurate manual response (2.6% of search trials) were excluded from RT analyses. Altogether, 11.7% of all trials were removed. All ANOVAs were Greenhouse-Geisser corrected to avoid issues of sphericity. For within-subject *t* tests, effect size is reported as Cohen's d_z (Lakens, 2013).

The data and stimulus program for all experiments are available on the Open Science Frameworks repository, https://osf.io/nwgz4/?view_only=4ef0f5dec2ba4b249523051976bf6afa. None of the experiments were preregistered.

Results

Search Trials

As shown in Figure 3A, manual RT was faster on repeat-location trials (633 ms) than change-location trials (701 ms), $t(23) = 8.66$, $p < .001$, $d_z = 1.77$. Manual error rates were also numerically lower on repeat-location trials (1.1%) than change-location trials (1.7%), although this difference was not statistically significant, $t(23) = 1.91$, $p = .068$, $d_z = 0.39$. Altogether, these results are consistent with an intertrial location priming account, whereby covert attention is biased toward the previous-trial target location. However, as previously reviewed, manual RTs do not, by themselves, directly indicate that attention shifted to the previous trial target location (Hilchey et al., 2019; Hilchey, Leber, et al., 2018; Hilchey, Rajsic, et al., 2018). This will be addressed in the next section.

Probe Trials

Participants reported on average 2.6 letters per trial and 85.4% of these letters were present in the probe array. Figure 3B depicts probe report accuracy as a function of search item (target, nonprimed distractor, and primed distractor) and target location (change-location trial vs. repeat-location trial). As can be seen, the data is broadly consistent with the predictions of the intertrial location priming account (Figure 2A). Probe report accuracy for the target was higher on repeat-location trials than change-location trials. Additionally, on change-location trials, probe report accuracy was higher at the primed distractor location than the average nonprimed distractor location.

We first conducted a one-way repeated measures ANOVA with a factor of search item (target, nonprimed distractor, primed distractor) on change-location trials. There was a clear main effect of search item, $F(2, 46) = 72.55$, $p < .001$, $\eta^2 = 0.76$. Preplanned *t* tests indicated that the target letter (55.5%) was more likely to be reported than the average nonprimed distractor letter (30.8%), $t(23) = 9.88$, $p < .001$, $d_z = 2.02$, and the primed distractor letter (39.0%), $t(23) = 6.89$, $p < .001$, $d_z = 1.41$. Crucially, the primed distractor letter (39.0%) was more likely to be reported than the average nonprimed distractor letter (30.8%), $t(23) = 7.80$, $p < .001$, $d_z = 1.59$. As shown in Figure 3B, this 8.2% *location priming effect* indicates that covert attention was biased to the primed distractor location above baseline levels of the nonprimed distractor locations.

A second prediction of the intertrial location priming account relates to priming of the target. Probe report accuracy should be higher at the target location on repeat-location trials than change-location trials. This is because the target is primed on repeat-location trials, but not change-location trials. As can be seen in Figure 3B, probe report accuracy at the target location was indeed higher on repeat-location trials (70.1%) than change-location trials (55.5%), $t(23) = 6.01$, $p < .001$, $d_z = 1.23$. This 14.5% *target repetition effect* further indicates that covert attention was biased towards the previous target location.

To ensure these intertrial priming effects were not a byproduct of saccades made on the previous trial, trials with eye movements on the previous trial were also removed and probe report accuracy was re-analyzed. Intertrial location priming effects remained even after these trials were removed: both the location priming effect (8.3%), $t(23) = 7.65$, $p < .001$, $d_z = 1.56$, and the target repetition effect (13.8%), $t(23) = 4.61$, $p < .001$, $d_z = 0.94$, were significant. Therefore, the intertrial location priming effects cannot be explained by oculomotor behavior from the previous trial.

Altogether, these results are consistent with an intertrial location priming account, which proposes that covert attention is attracted to the previous-trial target location.

Location Priming from Trial *n* – 1 to Trial *n* – 10

Previous studies have suggested that location priming may occur from several trials before the previous trial (Geyer & Müller, 2009; Maljkovic & Nakayama, 1996; Talcott & Gaspelin, 2020; Walthew & Gilchrist, 2006). In Figure 3C, location priming effects were examined on probe report accuracy as a function of influencing trial (trials *n* – 1 to *n* – 10). To accomplish this, we reclassified which locations were primed and nonprimed based upon each influencing trial. The location priming effect was then calculated as in the previous section: probe report accuracy for the primed distractor minus the average nonprimed distractor on change-location trials. The significance of each location priming effect was assessed with one-sample *t* tests. Because these *t* tests were exploratory, they were corrected for multiple comparisons with a False Discovery Rate correction to the *p* value (Benjamini & Hochberg, 1995). For interested readers, a full table of the results are included in the online supplemental materials.

As can be seen in Figure 3C, location priming effects from trial *n* – 1 were robust (8.2%), $t(23) = 7.79$, $p < .001$, $d_z = 1.59$. Just to be clear, the location priming effect from trial *n* – 1 is the same location priming effect depicted in Figure 3B. On trial *n* – 2, the location priming effect was reduced but still significant (4.3%), $t(23) = 3.14$, $p = .023$, $d_z = 0.64$. The remaining influencing trials resulted in nonsignificant location priming effects (*p*'s > .10). This analysis indicates location priming on probe report is strongest for the previous trial (trial *n* – 1), but there are modest location priming effects from trials beyond the previous trial (see also Maljkovic &

Nakayama, 1996; Talcott & Gaspelin, 2020).

Location Priming by Previous Trial Type

In the supplemental material, an exploratory analysis examined whether location priming effects on probe report and manual RT were stronger when the previous trial was a search trial as opposed to a probe trial. If location priming is truly the result of a search-related cognitive process, location priming effects should be larger following a search trial than following a probe trial. Indeed, location priming effects on probe report were much stronger after search trials (12.0%) than after probe trials (0.0%), $t(23) = 4.31$, $p < .001$, $d_z = 0.88$. These results indicate that location priming effects on probe report largely originate from search-related processes for a target item during the previous trial. Similarly, location priming effects on manual RT were larger following a search trial (88 ms) than a probe trial (19 ms), $t(23) = 4.95$, $p < .001$, $d_z = 1.01$. However, we urge some caution in interpreting this effect because the probe report display also involves multiple shifts of covert and overt attention (i.e., looking for letters to click), which could also disrupt any location priming from the previous trial.

Discussion

In Experiment 1, participants performed a capture-probe paradigm adapted to examine intertrial location priming. The results unanimously suggested that covert attention was attracted to the target location from the previous trial. On search trials, responses were faster on repeat-location trials than change-location trials. On probe trials, probe report accuracy was higher for primed distractors than the average nonprimed distractor. Additionally, probe report accuracy was improved for targets on repeat-location trials compared to change-location trials. Altogether, the results are consistent with an intertrial location priming account whereby the previous-trial target location captures attention by increasing the attentional priority of the item at that location.

Experiment 2

Experiment 1 provided straightforward evidence that covert attention was attracted to the previous-trial target location. However, the probe duration was relatively long, which could have allowed multiple shifts of covert attention to occur. The search array appeared for 100 ms and was followed by a probe array for 200 ms. As a result, there was a 300-ms stimulus onset asynchrony between the appearance of the search array and the appearance of the pattern mask. Given that shifts of covert attention are estimated to occur within 35 to 100 ms of the appearance of a stimulus (Horowitz et al., 2009; Tsal, 1983; but see Duncan et al., 1994; Ward et al., 1996 for longer estimates), the possibility that multiple shifts of covert attention occurred cannot be entirely ruled out. This is important because it is possible that attention shifted to the primed location only after the initial shift of covert attention to the target stimulus.

Experiment 2 therefore used a brief probe duration that should prevent multiple shifts of covert attention from occurring (Gaspelin et al., 2015, Exp. 4). On probe trials, the initial preview of the search array was removed and the probe array appeared for only 100 ms before being masked. The predicted patterns of results are identical to Experiment 1 (Figure 2).

Method

The methods used in Experiment 2 were identical to Experiment 1 except for the following changes.

A new sample of 24 participants was collected, and we chose this sample size a priori to be consistent with Experiment 1. Given the observed effect size of the location priming effect in Experiment 1 ($d_z = 1.59$), eight participants would be needed to achieve 95% power. If we alternatively used the target repetition effect ($d_z = 1.29$), eleven participants would be needed to achieve 95% power. In either case, the current sample size should be sufficiently powered to detect location priming effects. Two participants were replaced for generating eye movements on more than 25% of trials and one participant was replaced due to an inability to calibrate the eye tracker camera during the experimental session. Of the final sample, 13 participants were women and 11 were men with a mean age of 20.3 years.

The timing of the probe stimuli was reduced to prevent multiple shifts of attention (Gaspelin et al., 2015, Exp. 4). On probe trials, after the fixation requirement was met, the probe array (i.e., letters and shapes) now appeared for a duration of 100 ms and the letters were then immediately masked (#'s) for 500 ms. Referring to Figure 1A, on probe trials, there was no longer a search array preview and the probe array duration was reduced to 100 ms. Thus, the amount of time participants had to shift covert attention before the offset of the probe letters was only 100 ms. This brief probe duration also further ensures that probe letters cannot be fixated, and any saccadic eye movements triggered by the search array would arrive in vain to the location only after the probe display had disappeared. In Experiment 2, an average of 19.1 probe trials (*SD* = 4.8) occurred on repeat-location trials while 98.1 probe trials (*SD* = 5.6) occurred on change-location trials.

Aberrant trials were identified using the same criteria as in Experiment 1. Trials were excluded if gaze exceeded 1.5° from central fixation (9.5% of all trials). Furthermore, search trials were excluded if the participant made an erroneous manual response (2.8% of search trials) or had an abnormal RT (less than 200 ms or greater than 2.5 SDs from that subject's mean; 3.0% of search trials). Altogether, 12.6% of all trials were removed in Experiment 2. All Bayes factors (null/alternative) were calculated in JASP using the default prior (*r*-scale = .707).

Results

To summarize, the results are similar to Experiment 1. There was a location priming effect on manual RT. In addition, probe report accuracy was (a) higher for primed distractors than the baseline level of nonprimed distractors (a location priming effect), and (b) higher for targets on repeat-location trials than change-location trials (a target repetition effect).

Search Trials

As shown in Figure 4A, manual RT was faster on repeat-location trials (615 ms) than change-location trials (666 ms), $t(23) = 8.94$, $p < .001$, $d_z = 1.83$. Error rates were also numerically lower on repeat-location trials (1.4%) than change-location trials (2.1%), although this effect was not statistically significant, $t(23) = 1.51$, $p = .144$, $d_z = 0.31$.

Probe Trials

On average, participants reported 1.9 letters per trial and 64.5% of these letters were present in the probe array. Figure 4B depicts probe report accuracy as a function of search item for both repeat- and change-location trials. As can be seen, the results are quite similar to Experiment 1. On change-location trials, probe report accuracy at the primed distractor location was higher than the baseline level of the average nonprimed distractor location. Additionally, probe report accuracy for the target item was greater on repeat-location trials compared to change-location trials. This is consistent with the predictions of an intertrial location priming account (Figure 2A).

A one-way within-subject ANOVA was conducted on probe report accuracy with the factor of search item (target, nonprimed distractor, primed distractor) on change-location trials. There was a significant main effect of search item, $F(2,46) = 20.94$, $p < .001$, $\eta^2 = 0.48$. That is, probe report accuracy was higher at the target location (27.2%) than at the average nonprimed distractor location (17.7%), $t(23) = 5.61$, $p < .001$, $d_z = 1.15$. Critically, probe report accuracy was greater at the primed distractor location (25.7%) than at the average nonprimed distractor location (17.7%), $t(23) = 6.62$, $p < .001$, $d_z = 1.35$. This 8.1% location priming effect indicates that covert attention was allocated to the primed distractor above the baseline level of the nonprimed distractors. Furthermore, probe report accuracy at the primed location (25.7%) was no different than at the target location (27.2%), $t(23) = 0.85$, $p = .406$, $d_z = 0.17$, $BF_{01} = 3.37$, suggesting that guidance to the primed location rivaled guidance to the target location.

We also assessed whether probe recall at the target location was greater on repeat-location trials than change-location trials. Figure 4B shows higher probe report accuracy at the target location on repeat-location trials (38.7%) than on change-location trials (27.2%), $t(23) = 4.21$, $p < .001$, $d_z = 0.86$. This 11.5% target repetition effect demonstrates further evidence for the intertrial location priming account, indicating that covert attentional allocation to the target was more likely when it appeared at the same location as on the prior trial.

As in Experiment 1, we repeated this analysis excluding trials in which an eye movement was made on the previous trial. After these trials were excluded from the analysis, the location priming effect (8.7%), $t(23) = 6.74$, $p < .001$, $d_z = 1.38$, and the target repetition effect (12.0%), $t(23) = 4.16$, $p < .001$, $d_z = 0.85$, remained significant. Thus, these intertrial priming effects cannot be explained by eye movements on the previous trial.

Experiment 1 vs. Experiment 2

Experiment 1 and 2 were identical, except that the probe duration was reduced to 100 ms in Experiment 2. As a result, overall probe accuracy was lower in Experiment 2 (20.5%) than in Experiment 1 (36.4%), $t(46) = 5.17$, $p < .001$, $d = 1.49$. Reducing the probe duration limits the number of covert attentional shifts that can occur and therefore reduces overall probe accuracy (Gaspelin et al., 2015). This also potentially limits the time for explicit search goals to guide attention to the target stimulus. This is evidenced by the fact that target enhancement effects (i.e., the difference in probe report accuracy for the target versus nonprimed distractor on change-location trials) were significantly reduced in Experiment 2 (9.5%) compared to Experiment 1 (24.8%), $t(46) = 5.03$, $p < .001$, $d = 1.45$.

Importantly, the location priming effect in Experiment 2 (8.1%) was nearly identical to the location priming effect from Experiment 1 (8.2%), $t(46) = 0.06$, $p = .950$, $d = 0.02$, $BF_{01} = 3.47$. Similarly, there was also not a significant reduction in the target repetition effect in Experiment 2 (11.5%) compared to Experiment 1 (14.5%), $t(46) = 0.41$, $p = .683$, $d = 0.12$, $BF_{01} = 2.61$. This suggests that location priming effects were relatively unaffected by the reduced probe duration.

Location Priming from Trial *n* – 1 to Trial *n* – 10

We also examined location priming effects from trials *n* – 1 to trials *n* – 10. As can be seen in Figure 4C, there were strong location priming effects on trial *n* – 1 (8.1%), $t(23) = 6.09$, $p < .001$, $d_z = 1.24$. The other influencing trials did not produce significant location priming effects (*p*'s > .10). A full report (means, t-values, p-values) on this analysis can be found in the supplemental material for this article. Altogether, this suggests that location priming primarily results from the previous trial (but see Experiments 1 and 3).

Location Priming by Previous Trial Type

In the supplemental material, an exploratory analysis was performed to assess location priming effects as a function of whether the previous trial was a search trial or probe trial. As in Experiment 1, location priming effects on probe report accuracy were larger when the preceding trial was a search trial (10.5%) than a probe trial (2.1%), $t(23) = 3.24$, $p = .004$, $d_z = 0.66$. Location priming effects on manual RT were also larger for search trials preceded by a search trial (67 ms) compared to a probe trial (8 ms), $t(23) = 5.13$, $p < .001$, $d_z = 1.05$. This is consistent with the notion that the location priming effect on probe report accuracy results from attentional processes related to visual search on the previous trial. Again, we urge some caution in interpreting this result because it is also plausible that the probe response (which involved multiple shifts of attention) could also disrupt location priming.

Discussion

Experiment 2 was identical to Experiment 1, except that the probe duration was reduced to limit the number of attentional shifts that could occur during the probe display. Although this decreased overall probe report accuracy, there were still strong intertrial location priming effects. On search trials, RTs were faster on repeat-location trials than change-location trials. On probe trials, probe report accuracy was higher for the primed distractor than the baseline level of the nonprimed distractors. Additionally, the target letter was more likely to be reported on repeat-location trials than on change-location trials. Interestingly, the magnitude of the location priming effect (8.1%) was not reduced by the shortened probe duration compared to Experiment 1 (8.2%). Altogether, these results indicate that covert attention was rapidly allocated to the previous-trial target location, consistent with an intertrial location priming account.

Experiment 3

In Experiments 1 and 2, visual search was relatively difficult due to the high target-distractor similarity and heterogenous distractor shapes (Duncan & Humphreys, 1989). As a result, the target may have been a relatively weak competitor for attentional allocation. In fact, it has been suggested that such search displays may be so difficult that participants stop using an attentional priority map altogether (Liesefeld & Müller, 2019, 2020). Experiment 3 therefore presented the target amongst homogenously shaped distractors, which should cause the target item to "pop out" and strongly attract attention (Theeuwes, 1992; Bacon & Egeth, 1994). If intertrial location priming occurs even under these conditions, this would indicate that location priming is a strong effect that can overpower a highly salient target.

Method

The methods used in Experiment 3 were identical to Experiment 2, except for the following changes.

First, a new sample of 24 participants was collected (16 women and 8 men with a mean age of 19.7 years). Second, the distractors were changed to a homogenous set of either circles or diamonds. The homogenous distractor set was always selected as the opposing target shape. The identity of the target shape was held constant for the entire experimental session (e.g., always diamond). Thus, participants now searched for either a circle amongst diamonds or a diamond amongst circles depending on the counterbalancing condition. In Experiment 3, an average of 17.5 probe trials (*SD* = 3.8) occurred on repeat-location trials while 98.0 probe trials (*SD* = 8.3) occurred on change-location trials.

Aberrant trials were rejected using the same criterion as in Experiment 1. Trials were excluded if participants failed to maintain central fixation (7.6% of all trials). Additionally, search trials were excluded if they contained abnormal manual RT (2.5% of search trials) or if an erroneous manual response was made (2.5% of search trials). Altogether, 10.5% of trials were rejected.

Results

The results are similar to Experiments 1 and 2. There was a location priming effect on manual RT, albeit smaller. In addition, probe report accuracy was higher for primed distractors than the baseline level of nonprimed distractors and the magnitude of this location priming effect was not reduced compared to Experiments 1 and 2.

Search Trials

Manual RTs were generally faster in Experiment 3 (548 ms) than Experiment 1 (690 ms), $t(46) = 7.11, p < .001, d = 2.05$, or Experiment 2 (657 ms), $t(46) = 6.16, p < .001, d = 1.78$, indicating the target saliency manipulation was successful. As depicted in Figure 5A, manual RT was also faster on repeat-location trials (536 ms) than on change-location trials (550 ms), $t(23) = 3.47, p = .002, d_z = 0.71$. There were no differences in error rates on repeat-location trials (1.3%) and change-location trials (1.9%), $t(23) = 1.28, p = .215, d_z = 0.26$.

Probe Trials

Participants reported 1.8 letters on average and 74.1% of these were present in the display. Probe report accuracy is depicted in Figure 5B as a function of search item on repeat- and change-location trials. As can be seen, there were large intertrial location priming effects just as in Experiments 1 and 2.

A one-way within-subject ANOVA was conducted on probe report accuracy as a function of search item on change-location trials. There was a significant main effect of search item, $F(2,46) = 48.63, p < .001, \eta^2 = 0.68$. Probe report accuracy was higher at the primed distractor location (25.6%) than the average nonprimed distractor location (17.6%), $t(23) = 5.78, p < .001, d_z = 1.18$. This 8.0% location priming effect suggests that initial shifts of covert attention are attracted to recent target locations, even under relatively easy visual search.

Probe recall for the target letter was assessed as a function of whether the target repeated or changed locations from the previous trial. As seen in Figure 5B, probe report accuracy for the target letter was improved on repeat-location trials (43.8%) compared to change-location trials (37.7%), $t(23) = 2.09, p = .048, d_z = 1.00$. This 6.1% target repetition effect provides further evidence that the previous-trial target location attracts covert attention beyond baseline levels.

As in Experiment 1 and 2, trials were removed if an eye movement had been made on the previous trial and probe report accuracy was reassessed. Even after the removal of these trials, both the location priming effect (8.2%), $t(23) = 6.05, p < .001, d_z = 1.23$, and the target repetition effect (6.8%), $t(23) = 2.10, p = .047, d_z = 0.43$, remained significant. This indicates that intertrial priming effects cannot be attributed to saccadic behavior on the previous trial.

Experiment 2 vs. Experiment 3

Experiment 3 was identical to Experiment 2, except search was made easier by making the target salient. To investigate the success of this manipulation, we assessed target enhancement effects (i.e., probe report accuracy for the target minus the average nonprimed distractor), which should be greater in Experiment 3 compared to Experiment 2. Indeed, the target enhancement effect was greater in Experiment 3 (20.1%) than in Experiment 2 (9.5%), $t(46) = 3.87, p < .001, d = 1.12$, suggesting the difficulty manipulation was successful.

Despite increasing attentional guidance to the target, the location priming effect in Experiment 3 (8.0%) was not reduced from Experiment 2 (8.1%), $t(46) = 0.10, p = .922, d = 0.03$, $BF_{01} = 3.48$. Additionally, although the target repetition effect in Experiment 3 (6.1%) was numerically reduced from Experiment 2 (11.5%), this reduction was not significant in a between-subject comparison, $t(46) = 1.33, p = .189, d = 0.39$, $BF_{01} = 1.69$. Altogether, these results indicate intertrial location priming effects strongly influence attentional allocation during search, even under relatively easy visual search. In other words, a salient target did not eliminate intertrial location priming effects on probe report.

We also compared the intertrial location priming effect on manual RT between Experiments 2 and 3. The priming effect on manual RT was reduced in Experiment 3 (14 ms) from Experiment 2 (51 ms), $t(46) = 5.28, p < .001, d = 1.52$. However, it is important to note that manual RT effects may not be a good indicator of initial attentional allocation. For example, if the target is a popout, it may be quickly located after attention is initially misdirected to the primed location. This might result in a faster correction to the allocation of attention, resulting in a reduced latency-based location priming effect without affecting the probability that attention was initially directed to the primed location (see also Gaspelin et al., 2016).

Location Priming from Trial *n* – 1 to Trial *n* – 10

Location priming effects were examined across several influencing trials to trial *n* – 10. As can be seen in Figure 5C, there was a strong location priming effect on trial *n* – 1 (8.0%), $t(23) = 5.78$, $p < .001$, $d_z = 1.18$. The location priming effect was reduced but remained significant from trial *n* – 2 (4.6%), $t(23) = 3.66$, $p = .004$, $d_z = 0.75$, trial *n* – 4 (3.8%), $t(23) = 4.05$, $p = .003$, $d_z = 0.83$, and trial *n* – 5 (2.8%), $t(23) = 3.02$, $p = .015$, $d_z = 0.62$. The remaining influencing trials failed to reach significance (*p'*s > .10; for a summary, see the supplemental material). Altogether, these results suggests that location priming effects are largest from trial *n* – 1, but may also result from priming of earlier trials.

Location Priming by Previous Trial Type

In the supplemental material, an exploratory analysis was used to investigate probe report accuracy and manual RT as a function of whether the previous trial was a search trial or probe trial. As in the previous experiments, location priming effects on probe report accuracy were larger when a probe trial had been preceded by a search trial (10.5%) than when it had been preceded by a probe trial (2.4%), $t(23) = 3.44$, $p = .002$, $d_z = 0.70$. Additionally, location priming effects on manual RT were larger on search trials preceded by a search trial (17 ms) than a probe trial (0 ms), $t(23) = 2.33$, $p = .029$, $d_z = 0.48$. This result provides support for the notion that location priming effects stem from search-related processes on the previous trial.

Discussion

Experiment 3 was identical to Experiment 2, except that the target was a popout shape amongst homogenous distractors. This manipulation did improve guidance to the target stimulus as evidenced by enhanced probe report of the target compared to Experiment 2. Despite this increased salience of the target, Experiment 3 did not eliminate the location priming effects on probe report. Probe report accuracy was greater at the primed distractor location compared to baseline levels. In addition, probe recall was still significantly enhanced for targets when they repeated locations than when they changed locations. Altogether, these results suggest that intertrial location priming is a powerful determinant of attentional allocation and is not eliminated by making the target salient.

General Discussion

Recent models of attention have increasingly suggested that selection history may play a powerful role during visual search (Awh et al., 2012; Kristjansson, 2008; Wolfe, 2021). One form of selection history is intertrial location priming, whereby visual attention is purportedly attracted to the target location from the previous trial (Geyer et al., 2007; Geyer & Müller, 2009; Maljkovic & Nakayama, 1996; Talcott & Gaspelin, 2020; Tower-Richardi et al., 2016; Walthew & Gilchrist, 2006). An unresolved question is whether intertrial location priming truly influences covert attentional allocation (Maljkovic & Nakayama, 1996) or instead merely influences post-perceptual stages after the target is found (Hilchey, Rajsic, et al., 2018). Problematically, most previous studies have used latency-based metrics that cannot distinguish between these two accounts. The current study therefore used the capture-probe paradigm (Gaspelin et al., 2015), which provides a "snapshot" of covert attentional allocation during visual search. This allowed for the direct assessment of whether covert attention is biased toward the primed location.

In Experiment 1, participants searched for a specific target shape (e.g., diamond) amongst heterogeneous distractor shapes and made a speeded buttonpress to the location of a dot inside. The target location was randomly selected, so there should have been no incentive to prioritize previous target locations. On probe trials, letters were briefly superimposed over the search items before disappearing and participants attempted to recall as many probe letters as possible. Probe report accuracy was then used to infer the relative probability that a given location was covertly attended. Interestingly, probe report accuracy was much higher at the primed distractor location (39.0%) than the baseline level of the nonprimed distractor locations (30.8%): an 8.2% location priming effect. These results indicate that covert attention was attracted to the previous target location on the current trial, supporting an intertrial location priming account.

Experiment 2 was identical to Experiment 1, except that the probe duration was reduced to prevent multiple shifts of covert attention, allowing us to isolate the initial shift of covert attention. The reduced duration of the probe display decreased overall probe accuracy. There were still robust location priming effects on probe trials, replicating the basic results of Experiment 1. Probe report accuracy was greater for letters at the primed distractor location (25.7%) than at the average nonprimed distractor location (17.7%): an 8.1% location priming effect. Like Experiment 1, this suggests that covert attention is attracted to the target location from the previous trial.

Experiment 3 was identical to Experiment 2, except that the target was made salient to assess whether location priming can overpower strong attentional guidance to a target stimulus. Indeed, target enhancement effects on probe report were doubled in Experiment 3 (20.1%) from Experiment 2 (9.5%), suggesting that the target was much easier to find. Critically, probe report accuracy was again higher at primed distractor locations (25.6%) than nonprimed distractor locations (17.6%): an 8.0% location priming effect. Thus, even when the target was relatively easy to find, location priming still strongly influenced covert attentional allocation (see also Talcott & Gaspelin, 2020, Exps. 4–5).

Altogether, the current results indicate that the previous-trial target location attracts covert attention, which is consistent with accounts suggesting that intertrial location priming influences attentional allocation. These findings fit well with the broader literature showing that attentional selection is biased toward locations that previously contained the search target. Converging evidence that location priming can influence attentional selection has come from studies of manual RT (Geyer et al., 2007; Geyer & Müller, 2009; Maljkovic & Nakayama, 1996; Tanaka & Shimojo, 1996, 2000; Tower-Richardi et al., 2016), eye movements (Bansal et al., 2021; Talcott & Gaspelin, 2020; Walthew & Gilchrist, 2006), fMRI (Brinkhuis et al., 2020; Geng et al., 2006; Kristjánsson et al., 2007), and psychophysical measurements (Ásgeirsson et al., 2014). It is important to highlight that the current location priming effects on probe report and search RTs cannot be explained as a mere oculomotor bias, because eye movements were prohibited during the current task.

The current study suggest that intertrial location priming effects cannot be *entirely* explained as the priming of some post-perceptual process (Hilchey, Rajsic, et al., 2018). The probe results provide clear evidence that covert attention was directed to the primed location at above baseline levels. This is not to say, however, that location priming *only* influences attentional allocation. It is entirely plausible that the prior target location has separable influences on both attentional allocation and post-perceptual processes (see also Kristjánsson & Ásgeirsson, 2019). Importantly, these effects may summate and result in location priming effects traditionally observed on manual RT (e.g., Geyer et al., 2007; Geyer & Müller, 2009; Maljkovic &

Nakayama, 1996; Sauter et al., 2018; Tanaka & Shimojo, 1996, 2000).

The exploratory analyses in the current study suggest that intertrial location priming may linger for several trials, particularly when the target is a popout item (i.e., Experiment 3; see also Geyer & Müller, 2009; Maljkovic & Nakayama, 1996). However, while there is some evidence of location priming effects from trials beyond the immediately preceding trial in Experiments 1 and 2 under difficult search conditions, these effects were relatively weak (see also Talcott & Gaspelin, 2020). Future studies may be needed to more definitively determine whether intertrial location priming can occur from several previous influencing trials.

We found no evidence that the previous-trial target location was inhibited, as predicted by intertrial location suppression accounts (Hilchey, Rajsic, et al., 2018). Manual RT was faster on repeat-location trials compared to change-location trials, not slower as predicted by an intertrial location suppression account. Additionally, probe report was improved, not reduced, at the previous-trial target location. Given that the capture-probe technique was specifically developed to study inhibition of attention (Chang & Egeth, 2019; Feldmann-Wüstefeld et al., 2020; Gaspelin et al., 2015; Gaspelin & Luck, 2018a, 2018b), it should have also been sensitive to detect inhibitory effects due to intertrial location suppression. Future research is needed to definitively resolve why some paradigms produce evidence of intertrial location suppression whereas others do not (Dodd et al., 2009; Tanaka & Shimojo, 1996, 2000) and further understand the role of integration effects in intertrial priming (Hilchey et al., 2019; Hilchey, Leber, et al., 2018; Hilchey, Rajsic, et al., 2018).

The current results fit with the broader literature suggesting that selection history may have separable influences from explicit goals on visual search (Awh et al., 2012). However, it is worth mentioning that the relationship between intertrial priming effects and explicit guidance of visual attention is somewhat unclear. On the one hand, intertrial location priming could be the result of implicit learning that is a form of attentional guidance that is unique from explicit goals (i.e., selection history; Awh et al., 2012; Lamy & Kristjánsson, 2013). On the other hand, it is also possible that intertrial priming could modulate explicit attentional goals about expected target features or locations. When a target appears at a specific location on one trial, participants might explicitly anticipate that the target will appear there again and prioritize that location on the next trial. There are some hints against the latter interpretation of location priming effects (Kristjánsson & Campana, 2010; Maljkovic & Nakayama, 1996; Talcott & Gaspelin, 2020). For example, Talcott and Gaspelin (2020, Exp. 2) had participants perform a search task in which the target location *never repeated*, and participants were directly informed of this relationship. Still, first eye movements were strongly biased toward the previous trial target location. This result suggests that an explicit goal cannot overpower implicit guidance toward the previous target location. Nonetheless, it is possible that stronger manipulations could eliminate intertrial location priming effects. One possibility is that reminding that participants to ignore the previous-trial target location caused a kind of white bear effect (Moher & Egeth, 2012; Tsal & Makovski, 2006), whereby attention became attracted to the location they were instructed to ignore. In any case, the role of explicit goals in intertrial priming effects will certainly be an important question for future research.

Another remaining question regards the underlying cognitive processes behind intertrial location priming. Intertrial priming effects are commonly attributed to short-term implicit memory systems (Maljkovic & Nakayama, 1996, 2000; for a review, see Kristjánsson & Campana, 2010). One possibility is that a “priority tag” is assigned to locations that recently held the target. This priority tag would increase the attentional priority of the previous-trial target location in the competition for attentional allocation on the next trial. The notion of tagging a location for later attentional allocation bears a strong resemblance to the *priority accumulation framework* (Gabbay et al., 2019; Lamy et al., 2018). According to the priority accumulation framework, a short-term mechanism stores the attentional weights on a priority map over time, such that recent events at a location influences the likelihood that attention is deployed to that location. Future research may attempt to further understand the mechanisms by which attention is biased toward the previous-trial target location.

The probe technique in the current study could be a useful tool to study how other forms of selection history influence attentional allocation. This could provide valuable insights about attentional biases due to factors such as value-driven guidance (Anderson et al., 2011), statistical learning (Geng & Behrmann, 2002), intertrial feature priming (Maljkovic & Nakayama, 1994; Shurygina et al., 2019), or contextual cueing (Chun & Jiang, 1998). If a given form of selection history influences attentional allocation, there should be evidence of enhanced probe report for search items that match recent experience or context. An important issue will be to establish a *neutral* baseline for comparison with the item matching recent experience. For example, in the current study, the baseline was established as probe report accuracy for the average nonprimed distractor location and this baseline level of report was compared with the primed location. Additionally, overall probe report accuracy across all experiments was equivalent on repeat-location trials (26.1%) as on change-location trials (26.4%), $t(71) = 0.71$, $p = .482$, $d = 0.08$, suggesting changes in probe report accuracy for an item is associated with an associated change in the competition for attentional allocation. Similar approaches of establishing a baseline and comparing this baseline with processing of other locations has been useful in studies of attentional capture (Gaspelin et al., 2015; Chang & Egeth, 2019) and of visual sensitivity in relation to saccade generation (Deubel & Schneider, 1996). Future research might also vary the type of probe stimulus used (e.g., letters versus Gabor patches) to answer more specialized questions, such as determining the spatial resolution of location priming effects (Hanning et al., 2019).

Finally, it is worth considering the potential effects of intertrial location priming on studies investigating attentional capture by salient stimuli. The current paradigm bears a strong resemblance to the additional singleton paradigm that has been extensively used to study attentional capture (Bacon & Egeth, 1994; Gaspelin et al., 2015; Theeuwes, 1992). It therefore seems highly likely that intertrial location priming has strongly influenced covert attentional allocation in many previous studies of attentional capture. Indeed, it has been well-documented that forms of feature-based priming can play a strong role in the magnitude of attentional capture effects observed in these paradigms (e.g., Adam et al., 2021; Becker, 2010; Gaspelin et al., 2019). It therefore important to understand whether location-based priming also strongly influences attentional capture in these paradigms.

In summary, the current study demonstrates clear evidence that perceptual processing is enhanced at the target location from the previous trial. This pattern of results suggests that selection history can powerfully influence attentional allocation during visual search. The current probe technique can easily be adapted to further assess whether other forms of selection history truly attract covert attentional allocation to items primed by recent experience.

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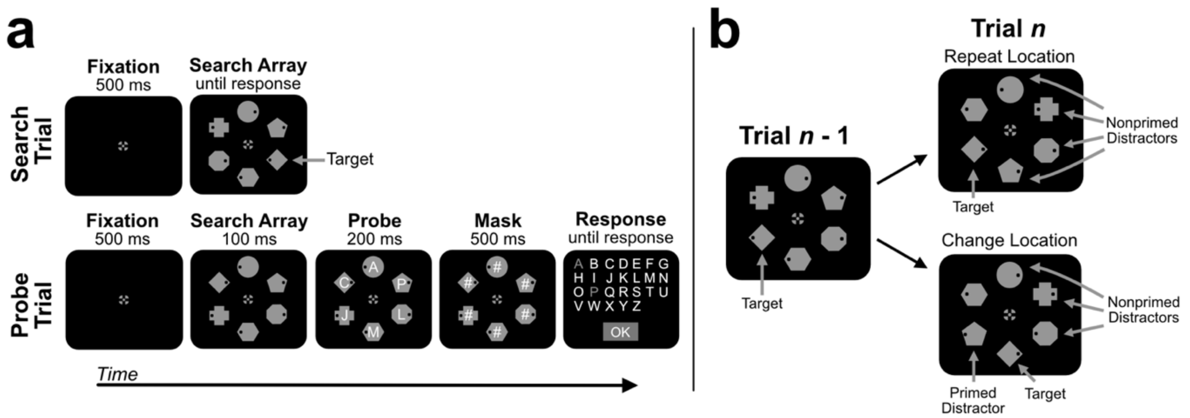

Figure 1. Stimuli and procedure for Experiment 1. (A) On search trials, participants searched for the target and reported the location of a black dot inside. On probe trials, the search array was briefly presented and then letters were superimposed onto each shape. This was followed by a pattern mask. Participants reported as many probe letters as possible. (B) The target appeared at a randomly selected location. On repeat-location trials, the target location on the current trial is primed. On change-location trials, the previous-trial target primes a distractor location on the current trial.

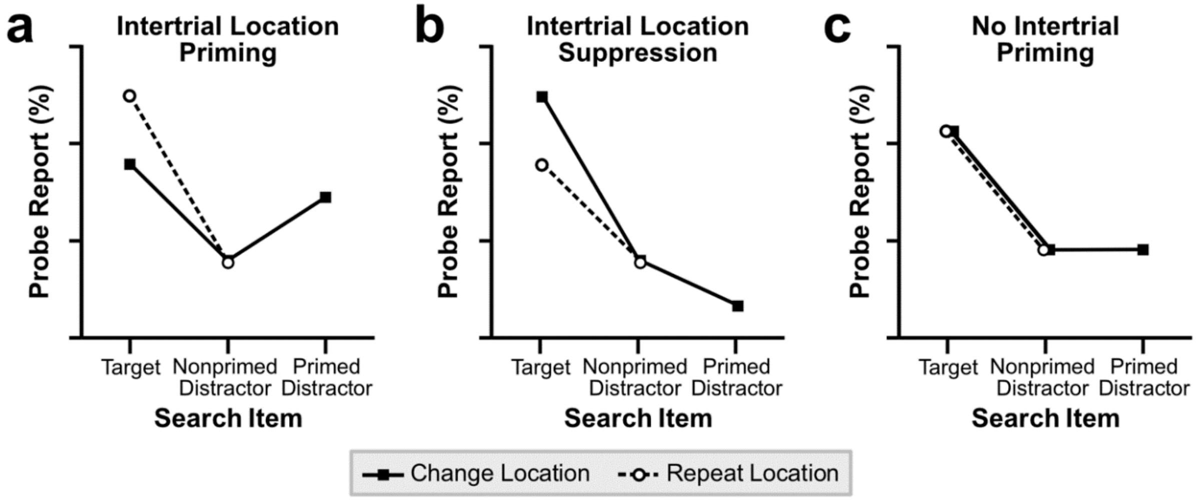

Figure 2. Theoretical predictions of probe task performance. (A) If the previous target location is enhanced, probe report accuracy should be improved at the primed distractor compared to the nonprimed distractor locations. (B) Conversely, if the previous target location is suppressed, probe report accuracy should be reduced at the primed distractor compared to the nonprimed distractor locations. (C) If the previous target location has no influence on attentional allocation, probe report accuracy should be equal at the primed distractor and nonprimed distractor locations.

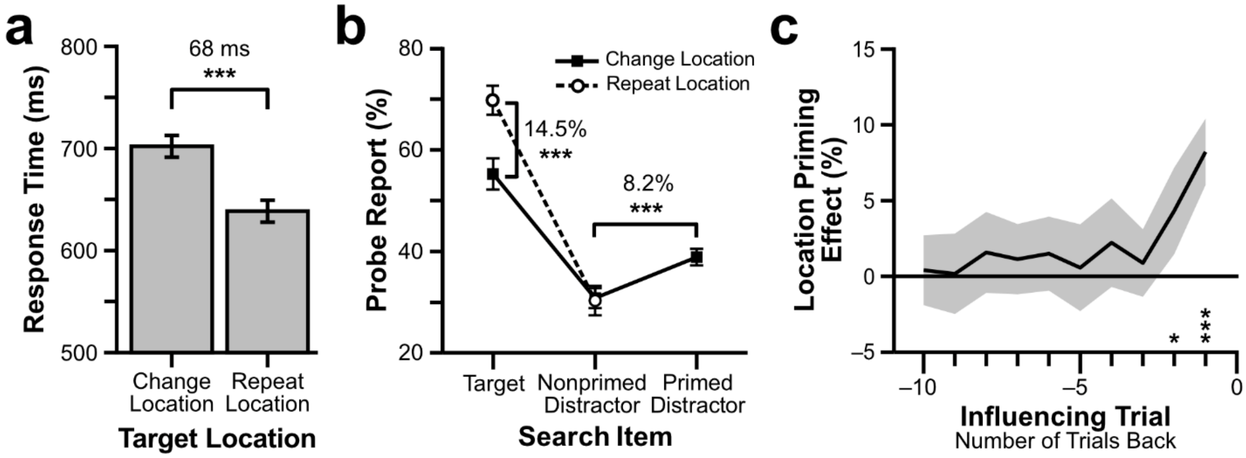

Figure 3. Results for Experiment 1. (A) Response time on search trials as a function of target location (change-location vs. repeat-location). (B) Probe report accuracy for letters presented at each search item as function of trial type. (C) Location priming effects as a function of influencing trial (trials *n* – 1 to *n* – 10). In all plots, error bars represent the within-subject 95% confidence interval (Cousineau, 2005; Morey, 2008). * *p* < .05, *** *p* < .001

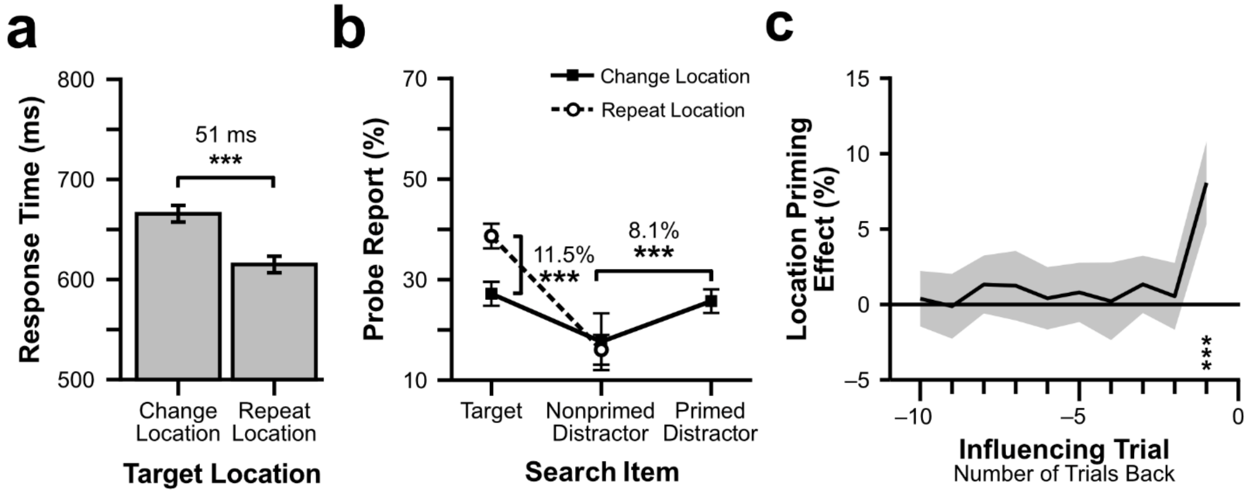

Figure 4. Results for Experiment 2. (A) Manual response time on search trials as a function of target location. (B) Probe report accuracy for letters presented at each search item on change-location trials versus repeat-location trials. (C) Location priming effects as a function of influencing trial (trials *n* – 1 to *n* – 10). * *p* < .05, *** *p* < .001

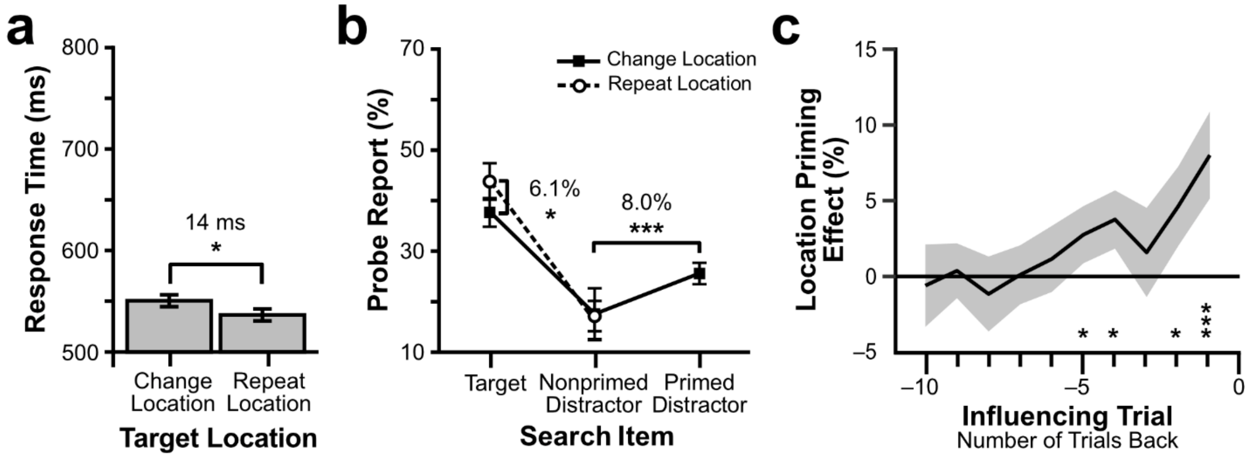

Figure 5. Results for Experiment 3. (A) Manual response time on search trials as a function of target location. (B) Probe report accuracy for letters presented at each search item on change-location trials versus repeat-location trials. (C) Location priming effects as a function of influencing trial (trials *n* – 1 to *n* – 10). * *p* < .05, *** *p* < .001