Memory for Gaze Cues Can Attenuate Change Blindness in the Flicker Paradigm

Original Research

Alexis Miller[1], Joshua Tolliver[1], D. Alexander Varakin[1]

[1]*Eastern Kentucky University, Richmond, Kentucky*

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Abstract

Introduction: Observers often pay attention to objects that are the target of another's gaze. The current experiments investigate if memory for gaze cues has similar effects on attention.

Methods: We used the flicker paradigm, in which participants searched for changes in pictures of real-world scenes. In experiment 1, half of the scenes depicted a person looking at the changing object, and the other half depicted no people. In experiment 2, none of the scenes in the flicker sequence contained people, but participants previewed pictures prior to the flicker sequence, and half of the previews depicted a person looking at the changing object.

Results: In both experiments, participants were faster to find changes when the changes were cued (Exp 1, $t(20) = 2.55$, $p = .02$; Exp 2, $t(49) = 7.18$, $p < .001$). Analysis of accuracy suggests it was not due to a speed-accuracy tradeoff.

Conclusions: These results suggest that memory for gaze cues may help guide attention. However, the results do not suggest one way or the other whether this effect is reflexive or unique to social cues.

Key Words: change detection, joint attention, scene perception

Corresponding author: D. Alexander Varakin, donald.varakin@eku.edu

Introduction

The world contains more information than an observer needs to process. Thus, attention restricts processing to a subset of available information. As such, observers need ways to help ensure that attention selects useful information. In social situations, it can be useful for observers to direct attention to what other people are paying attention[1].

Indeed, there is a large literature demonstrating that social cues, such as another person's gaze, affect attention[2]. Experiments have used a variety of stimuli (from schematic diagrams of eyes or cropped faces[3,4] to pictures of people in real world environments[5,6]) and tasks (from target detection[3], to studying pictures[6], to change detection[5]), to demonstrate that objects that are the target of another person's gaze are prioritized. However, most previous work has used perceived gaze cues that were visible while attentional deployment was measured. Given the dynamic nature of social interactions, it could be beneficial if observers could rely on *memory* for cues to guide attention. In some situations, memory can induce shifts of attention when a familiar face associated with a particular direction of gaze is encountered[4]. But can memory for social cues help guide attention when the cue is not visible at all? The current experiments utilized pictures of real-world environments and the flicker paradigm[7] to investigate this question.

In the flicker paradigm, participants are presented with two versions of a scene presented cyclically with a blank screen between each presentation[7]. The blank screen causes change blindness[8], and observers need to attend to the changing object to see the change[9]. The current experiments compared the time to find changes that were gaze targets to changes that were not. In Experiment 1, gaze cues were present while observers searched for the changes. In Experiment 2, gaze cues were presented before the flicker sequence, requiring the observers to rely on memory.

The purpose of the current experiments was to investigate whether short-term memory for gaze cues can influence attentional selection. Note that although this question was motivated by the idea that such memory might be useful in social situations, the current experiments were not designed to compare gaze cues to other kinds of cues, such as arrows. As such, in both experiments, change detection performance is compared between conditions in which there is a gaze cue (perceived in Experiment 1, from memory in Experiment 2) to conditions in which there is no gaze cue. If memory for recently cued objects can affect attentional selection, then participants should be able to find changes faster on trials in which there was a gaze cue compared to no-cue trials.

Scientific Methods

Participants

Twenty-one people from the EKU Psychology Department participant pool participated in Experiment 1, and fifty in Experiment 2 (age and gender were not recorded, but participation required normal or corrected-to-normal visual acuity). All participants read an informed consent statement prior to participating, as approved by the university's Institutional Review Board.

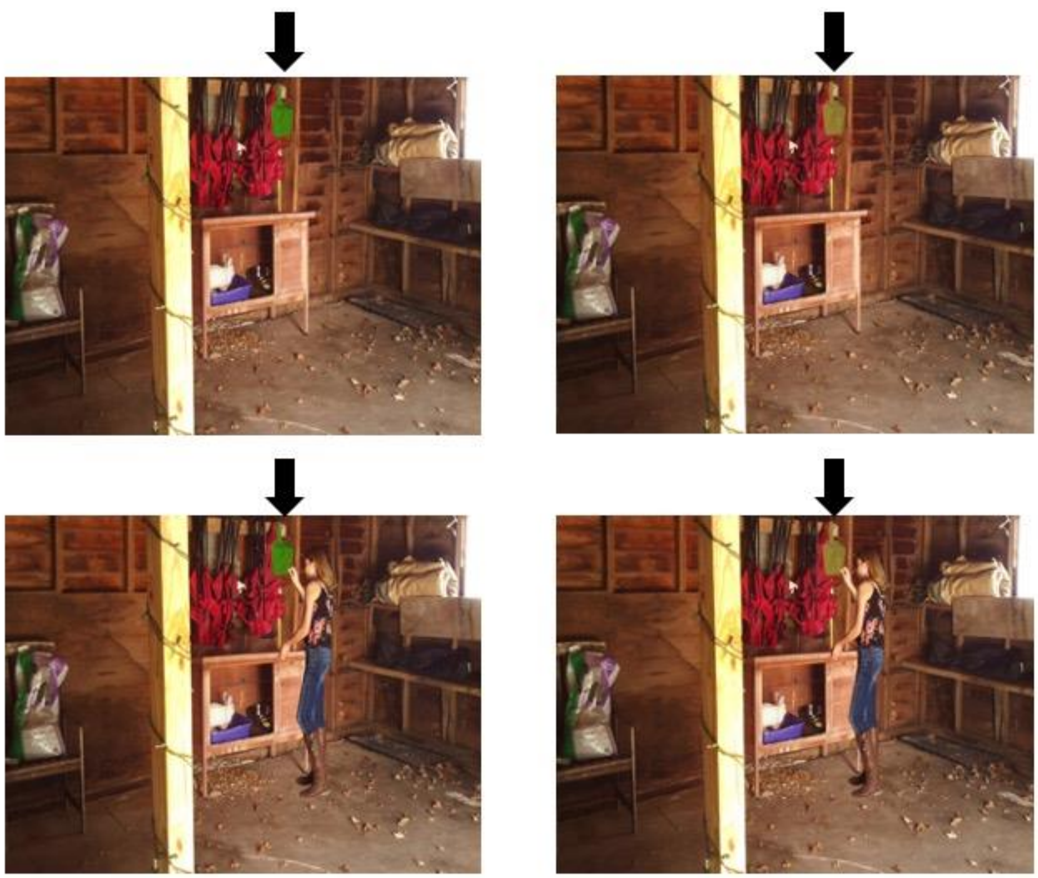

Figure 1.
Example stimuli. The top row shows a no-cue scene, and the bottom row shows a valid-cue scene. The changing object is a dustpan hanging on the wall, indicated by an arrow above the picture.

Protocol
Both experiments used a within-subjects design. There were two conditions: no-cue and valid-cue. In the no-cue condition, the scenes did not contain any people. In the valid-cue conditions, the scenes contained a person looking at and reaching for the changing object (see Figure 1). There were 10 trials per condition per participant, presented in a random order (randomized separately for each participant). Stimuli were created such that there were no-cue and valid-cue versions of each scene. Thus, the scenes used for the no-cue conditions for half the participants were used for the valid-cue conditions for the remaining participants.

Both experiments used the same stimuli, which were digitally manipulated photographs of various indoor and outdoor environments. To create the stimuli, separate photographs (dimensions 1024 x 768 pixels, resolution 72 x 72 pixels/inch) were taken of a single scene with a stabilized digital camera. The background photograph contained no people. In the valid-cue photograph, a person posed while looking at and reaching for the critical object (that would change in the flicker sequence). In order to ensure that the stimuli were identical across the conditions, except for the cue presence, the photographs were manipulated using GIMP[10]. First, the critical object's color in the background photograph was changed twice, ensuring that each version of the changing object was digitally altered. Next, the person from the valid-cue photograph was pasted into altered versions of the background photograph in the exact location they appeared in the valid cue photograph. Thus, there were no-low level differences between the different versions of the changing object in the no-cue and valid-cue stimuli, unlike some previous research which only statistically controlled for potential differences between no-cue and valid cue conditions[5].

In addition to the images that were used as stimuli, for each scene, a mask was created in order to determine whether the participant successfully clicked on the location of the changing object. The masks consisted of a white background with a black area (RGB (0, 0, 0)) corresponding to the location and shape of the changing object. Masks were never presented; when a participant clicked on the screen during a trial, the computer loaded (but did not display) the mask in order to determine if the pixels at the location of the click were black, and which feedback to present ("You found the change" vs. "Looks like you missed the change"). (Note: for some masks, a small number of pixels that were supposed to be RGB (0,0,0) were visibly black, but not RGB (0,0,0); this sometimes affected the feedback participants got after a mouse click, but did not affect the data analysis since we also had X, Y coordinates of mouse clicks). In both experiments, participants completed two practice trials prior to starting the main experiment. The flicker sequence was verbally described before participants started practice. On each trial, the computer monitor read "Press the spacebar when you are ready to begin the next trial". The flicker sequence commenced ~130ms after the spacebar press. In the flicker sequence, each version was presented in alternating fashion for 300ms with a 300ms blank screen in between each alternation (see Figure 2). Participants were instructed to click on the changing object. If after 90 seconds, no click was registered, the blank screen was eliminated from the sequence so the change would pop-out, and text appeared on the screen prompting participants to "click on the change". After the practice trials, participants completed 20 trials of the main experiment, which used a flicker sequence with the same parameters as practice. For experiment 1, half of the scenes in the flicker sequence contained valid cues, and half contained no cues. In experiment 2, on each trial a preview picture was presented for 1000ms (followed by a 600ms blank screen) prior to the onset of the flicker sequence. Half of the preview pictures contained valid cues, and the other half contained no cues. In both conditions in Experiment 2, the scenes presented in the flicker sequence contained no cues.

Statistical Analysis
Response time (RT) for accurate trials was the primary dependent variable (see Table 1 for descriptive statistics). Accuracy was also analyzed. Dependent samples t-tests, with alpha set at .05, were used to test for differences between valid-cue and no-cue conditions in each experiment. All analyses were performed is Python 3.7 using the pandas and scipy stats libraries in the Spyder integrated development environment.

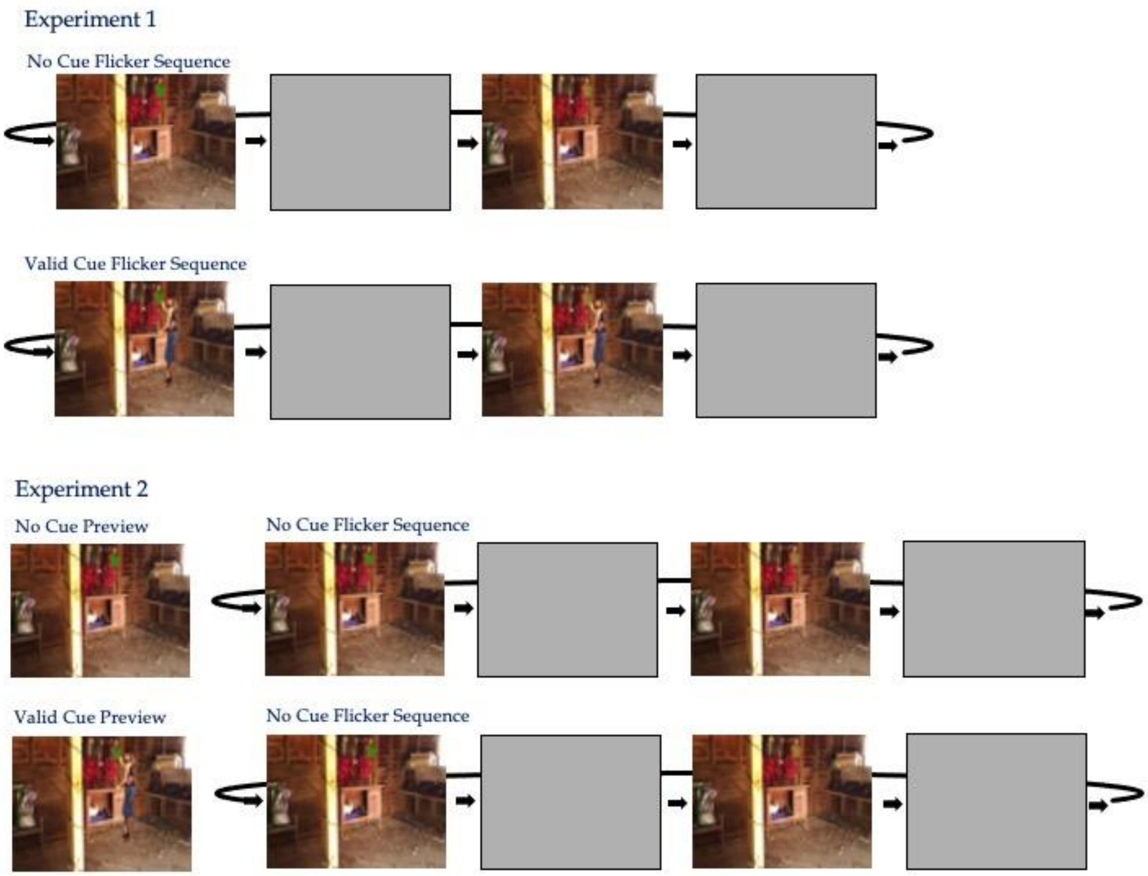

Figure 2.
Schamatic diagram of the no-cue and valid cue conditions from Experiments 1 and 2.

PsychoPy builder[11] loaded on an HP ProDesk with an Intel i7 CPU, NVIDIA NVS 310 GPU, and a 20-inch (diagonal) HP E201 monitor set at resolution of 1600 x 900 controlled stimulus presentation and recorded responses.

Results

In both experiments, changes were detected faster and more accurately in the valid-cue condition than the no-cue condition. The difference was significant only with RT (Exp 1, $t(20) = 2.55$, $p = .02$; Exp 2, $t(49) = 7.18$, $p < .001$), but not accuracy (Exp 1: $t(20) = 1.25$, $p = .22$; Exp 2: $t(49) = 0.43$, $p = 0.68$). This pattern of results suggest that valid-cues facilitated change detection, but not due to a speed-accuracy trade-off.

Table 1. Descriptive statistics for response time (RT, in seconds) and accuracy (%) for both experiments.

		No cue	Valid cue
Experiment 1 (n = 20)	RT	11.22 ± 4.58	7.34 ± 4.48
	Accuracy	80 ± 11	84 ± 9
Experiment 2 (n = 50)	RT	11.56 ± 7.26	4.11 ± 2.99
	Accuracy	79 ± 18	81 ± 14

Data are Means ± SD

Discussion

These results suggest memory for gaze cues can help guide attention about as effectively as perceived gaze cues in the flicker paradigm. While the stimuli and task used here were dissimilar to real-world interactions in important ways, the current experiments increase ecological validity because photographs of people are more realistic compared to the isolated faces that characterize much past work on gaze cues. Additionally, because of the way in which the current stimuli were constructed, we can be confident that the effect is not due to low-level perceptual differences between the changing objects in the no-cue and valid-cue conditions as in some previous work[5].

As mentioned in the introduction, it is important to note that the current experiments did not directly compare the effectiveness of gaze cues and other kinds of cues, such as symbolic or sensory cues[12]. As such, it is possible that the mechanisms by which observers found the changes are not specific to gaze cues or social stimuli, but are instead domain general mechanisms of attention and memory. Questions about the relative effectiveness of memory for non-social and social cues are theoretically interesting, but the current results do not provide evidence one way or the other. The current results also do not suggest, one way or the other, whether the memory cueing effect observed here occurs reflexively, or as a result of a deliberate strategy. Past work suggests that attentional orienting in response to gaze cues is strongly reflexive[3], and indeed, participants in the current experiments were not overtly instructed to rely on gaze cues to help find the changes. However, the gaze cue was also 100% valid, and participants may have figured that out quickly. Thus, current results demonstrate that memory for social cues can be used to facilitate change detection, but do not demonstrate the effect is reflexive, or rule out the possibility that memory for other kinds of cues can have similar effects.

Conclusions

Given the importance of gaze cues for helping maintain joint attention in social situations, the current results are important because they suggest short-term memory for gaze cues can be used to guide attention. While the current work does not directly address whether short-term memory for other kinds of cues may have similar effects, the results still suggest that observers may be able to maintain prioritization of relevant objects in dynamic situations in which cues are not visible at the time objects need to be attended.

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