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Research Article

Novelty Is Not Always the Best Policy

Inhibition of Return and Facilitation of Return as a Function of Visual Task

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ABSTRACT—*We report a study that examined whether inhibition of return (IOR) is specific to visual search or a general characteristic of visual behavior. Participants were shown a series of scenes and were asked to (a) search each scene for a target, (b) memorize each scene, (c) rate how pleasant each scene was, or (d) view each scene freely. An examination of saccadic reaction times to probes provided evidence of IOR during search: Participants were slower to look at probes at previously fixated locations than to look at probes at novel locations. For the other three conditions, however, the opposite pattern of results was observed: Participants were faster to look at probes at previously fixated locations than to look at probes at novel locations, a* facilitation-of-return *effect that has not been reported previously. These results demonstrate that IOR is a search-specific strategy and not a general characteristic of visual attention.*

To successfully navigate the visual world, one must efficiently direct attention to important features in the environment while simultaneously ignoring unimportant or distracting stimuli. One process that is thought to facilitate the selection of visual information is inhibition of return (IOR), in which return of attention to a recently inspected location is slower or less likely than direction of attention to a novel location. Since the initial discovery of IOR by Posner and Cohen (1984), researchers have posited that the purpose of IOR is to maximize the efficiency of visual search for an object by ensuring that attention is not returned to previously examined locations. Initial evidence that IOR influences search behavior was provided by Klein (1988; see also Müller & von Mühlenen, 2000; Takeda & Yagi, 2000), who found that the detection of a probe stimulus was impaired at locations that had been attended in a serial search task.

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Klein and MacInnes (1999) provided further evidence of a role for IOR in search using "Where's Waldo" displays. During search, participants had to make a saccade to a target probe appearing at a previously fixated or novel location. Saccadic reaction times (SRTs) to probes at one-back and two-back locations were slowed relative to SRTs to probes at novel locations, a finding indicative of IOR. These results are consistent with memory-based models of IOR, in which previously attended locations are tagged and held in memory so that attention does not return to them.

Further evidence that IOR both influences search and involves a memory component has been provided by studies investigating whether IOR occurs at several sequentially cued locations (Danziger, Kingstone, & Snyder, 1998; Dodd, Castel, & Pratt, 2003; Dodd & Pratt, 2007; Snyder & Kingstone, 2000; Tipper, Weaver, & Watson, 1996). For example, Snyder and Kingstone (2000) used a display of eight peripheral placeholders and six sequential cues on each trial, observing IOR for the five most recently cued locations only. This finding is consistent with the idea that IOR can influence search by biasing attention away from several sequentially attended locations, and at the same time suggests that the system has a limited capacity, with only a subset of locations held in memory at any given time.

Although there is ample evidence that IOR influences search behavior, IOR is often discussed as though it is a general characteristic of attention. That is, attention is thought to be slower to return to recently inspected locations regardless of the task set, despite the fact that there has been little systematic investigation of this issue. That Posner and Cohen (1984) observed an effect of IOR on target detection in a nonsearch task would seem consistent with this idea, but it is important to note that

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target-detection tasks are searchlike in that the overall goal is to shift attention to find a target in a display. It is not surprising, therefore, that IOR influences target detection.

In the present study, we examined whether IOR is specific to visual search tasks or is a general property of visual behavior.[1] Although a mechanism that biases attention to novel locations would clearly be advantageous to search, it is less clear that such a mechanism would be useful for other common visual tasks. IOR might be useful if an individual is trying to memorize a scene, as increasing the number of areas sampled may help to create a more complete representation of that scene. However, if one is trying to remember the details of a few prominent objects in a scene, the creation of a memory representation may be facilitated by returning to the locations of prominent objects (e.g., Henderson, Weeks, & Hollingworth, 1999). Similarly, if one is comparing two objects in a scene, a series of fixations between the two objects might be necessary. Such rapid alternations would be impaired by an IOR mechanism. A similar argument can be made for pleasantness judgments.

Given that many common visual tasks may be impaired by an IOR mechanism, it is important to determine whether IOR is limited to visual search (and potentially other tasks that would benefit from a novelty bias) or whether IOR extends to all types of visual tasks, which would be consistent with the assumption that IOR is a general property of visual attention. To this end, in the present study, we had participants view a set of scenes under four task conditions (search, memorize, rate pleasantness, or view freely) while we monitored their eye movements. If IOR is a general property of attention, then it would be expected in all four conditions even though task performance in the memory, pleasantness-rating, and free-viewing conditions would not necessarily benefit from a novelty bias. If, however, IOR is a process specialized for visual search, then it would be expected only in the search condition.

Numerous researchers have suggested that memory and IOR influence search, but this view is not without its critics. Although the research we have summarized is indicative of a role of IOR and memory in search, other researchers have suggested that such a role is limited (e.g., Gilchrist & Harvey, 2000) or nonexistent (Horowitz & Wolfe, 1998, 2001, 2003). Part of the difficulty in measuring IOR in search, however, is that there is no agreed-upon method of doing so. Consequently, in the present research, we used multiple measures to investigate the influence of IOR on performance. Our critical measure was SRTs to probes at previously fixated locations relative to SRTs to probes at novel locations. We expected that participants would be slower to look at probes appearing at previously fixated locations in the search condition, but the expectation for the other conditions was less clear. To obtain converging evidence of the presence or absence of IOR, we also examined the number of refixations individuals made during each trial, as well as the amount of time between refixations.

[1] Yarbus (1967) demonstrated that scan paths are affected by task set, but the influence of task set on IOR has yet to be determined.

METHOD

Participants

Forty-eight undergraduate students from the University of British Columbia and the University of Nebraska–Lincoln underwent individual 30-min sessions, receiving course credit as remuneration for participating in the study. Twelve of the students participated in each task condition. All had normal or corrected-to-normal vision and were naive about the purpose of the experiment.

Apparatus and Procedure

The eye tracker was an SR Research Ltd. EyeLink II system (Mississauga, Ontario, Canada), with high spatial resolution and a sampling rate of 500 Hz. For all participants, the dominant eye was monitored. Thresholds for detecting the onset of a saccadic movement were acceleration of $8000°/s^2$, velocity of 30°/s, and distance of 0.5° of visual angle. Movement offset was detected when velocity fell below 30°/s and remained at that level for 10 consecutive samples.

Stimulus displays were presented on two monitors, one for the participant and the other for the experimenter (real-time feedback to the experimenter allowed for recalibration when necessary). The average error in the computation of gaze position was less than 0.5°.

A nine-point calibration procedure was performed at the beginning of the experiment, followed by a nine-point calibration accuracy test. Calibration was repeated if any point was in error by more than 1° or if the average error for all points was greater than 0.5°.

The experiment, programmed in Visual C++, was individually conducted on a Pentium IV computer with a Dell monitor in a testing room equipped with soft lighting and sound attenuation. Participants were seated approximately 44 cm from the computer screen and made responses using both eye movements and the keyboard in front of them.

For all subjects, the experiment consisted of the presentation of 68 computer-generated natural scenes depicting common environments (e.g., rooms and locales). The scenes were adapted from a set used by Hollingworth (2007). Figure 1 presents a few examples of the scenes we used. Each scene had a small *N* or *Z* embedded in the picture for the purpose of the search task (described later in this section). At the beginning of each trial, a fixation point appeared in the middle of the screen; participants were instructed to look directly at the fixation point and press the space bar to initiate each trial. Each scene was displayed for 8 s, during which participants engaged in a primary task. On 36 of the 68 trials, a probe (a green circle, $71.9\ cd/m^2$, 1.0°) appeared at approximately the 6-s point. The probe occupied either a

Fig. 1. Examples of the computer-generated natural scenes that were used as stimuli in the present study.

novel location that had not been previously fixated (18 trials) or the location of a previous fixation (18 trials). When the probe occupied a previously fixated location, it appeared at a two-back location (two fixations previously), four-back location (four fixations previously), or six-back location (six fixations previously). We did not use a one-back probe, given Klein and MacInnes's (1999) mixed findings regarding one-back probes. Moreover, one-back probes always appear in a location that requires a saccade in a direction opposite to the immediately preceding saccade, so it is unclear whether longer SRT to one-back probes than to probes at a novel location reflects IOR or simply a low-level oculomotor compatibility effect.

Fixations were monitored in real time by the computer program to determine where the probe would appear. Participants were instructed that in addition to performing their primary task, they should look at the probe the moment they detected it.

There were four task-set conditions that were manipulated between subject groups. Participants in the search condition were told that the letter *N* or *Z* was present in each picture and that they were to search for the letter. At the end of each trial, participants made a key-press response to indicate whether an *N* or a *Z* had been present. The letter was very small and well camouflaged and could not be detected unless fixated. This ensured that participants in the other conditions were unlikely to detect the letter while viewing the scene. In addition, the inconspicuousness of the target ensured that participants searched for the entire 8 s. If the target had been easy to detect, early detection might have altered eye movement behavior. The majority of participants reported that they rarely, if ever, found the target; they typically searched for the entire 8 s during which the scene was visible.

The remaining participants were assigned to the memory, pleasantness-rating, and free-viewing conditions. In the memory condition, participants were asked to memorize each scene to prepare for a memory test at the end of the session (memory was not actually tested). In the pleasantness-rating condition, participants were asked to decide how much they liked each picture on a scale from 1 (*do not like the picture at all*) to 7 (*like* *the picture very much*) and responded via a key press at the end of each trial. Finally, in the free-viewing condition, participants were given no specific instruction and simply told to view each picture as they chose.

RESULTS AND DISCUSSION

Table 1 presents SRTs to probes for each probe location and task set; IOR values are also reported. The average number of fixations and refixations per trial, and the average elapsed time between refixations, are reported in Table 2.

If IOR is a general characteristic of visual behavior, we would expect that in all conditions, SRTs would be slower for probes appearing at previously fixated locations than for probes appearing at previously unfixated locations. Moreover, we would expect little difference in the number of refixations and time between refixations as a function of task condition.

Saccadic Reaction Times

The probe-detection task provides the most direct test of whether IOR influenced visual behavior in our various tasks. On more than 50% of probe trials, the first eye movement after the appearance of the probe was made to the probe. On a smaller proportion of trials, participants made one additional eye movement before looking at the probe, and on a few trials, they made more than one additional eye movement before looking at the probe or failed to look at the probe at all. In the analyses reported, we included only those trials on which participants looked at the probe immediately when it appeared. We also performed analyses that included trials on which one additional eye movement was made before probe fixation (these analyses included more than 90% of all probe trials), and the results were unchanged. Critically, there were no differences among the task conditions in the number of trials on which the probe was immediately fixated, fixated after one additional eye movement, or not fixated at all.

To determine whether SRTs were influenced by probe location and task set, we performed a mixed analysis of variance (ANOVA) with probe location as a within-subjects factor and task set as a between-subjects factor. There was a marginal effect of task set, $F(3, 44) = 2.37$, $p_{rep} = .83$, $\eta_p^2 = .14$. Critically, there was a strong interaction between probe location and task set, $F(9, 132) = 4.17$, $p_{rep} = .99$, $\eta_p^2 = .22$. As Table 1 shows, and as was confirmed by planned comparisons, there was strong evidence of IOR in the search task. Participants were significantly faster to make a saccade to a probe at a previously unfixated location than to make a saccade to a probe at a two-back or four-back location, $t(11) = -2.38$, $p_{rep} = .95$, and $t(11) = -3.67$, $p_{rep} = .95$, respectively. This pattern of results did not continue to the six-back location, but this is not surprising given evidence that IOR influences only the last five attended (fixated) locations in search and searchlike tasks (e.g., Snyder & Kingstone, 2000). The magnitude of IOR was larger for the four-back location than for the two-back location, but not significantly so.

Although there was strong evidence of IOR in the search task, the reverse pattern of results was observed for the other tasks: Participants were significantly faster to look at a probe at a previously fixated location than to look at a probe at a previously unfixated location. Planned comparisons revealed that participants were faster to look at two-back probes than to look at novel probes in the memory, pleasantness-rating, and free-viewing conditions (all p_{rep}s > .90), and were faster to look at four-back probes than to look at novel probes in the pleasantness-rating and free-viewing tasks (all p_{rep}s > .90). Only the pleasantness-rating task set elicited faster SRTs to six-back probes than to novel probes ($p_{rep} = .95$).

One concern when interpreting the SRT data for the different task sets is that participants in the search condition tended to look over a greater spatial area of the scene than did participants in the other three task conditions. Perhaps participants were

TABLE 1
Saccadic Reaction Times (SRTs; in Milliseconds) to Probes and Magnitude of Inhibition of Return (IOR) in the Four Task Conditions

	Probe location			
Task and measure	Novel	Two-back	Four-back	Six-back
Search				
SRT	254 (45)	324 (64)	336 (60)	256 (60)
IOR	—	−70	−82	−2
Memory				
SRT	293 (50)	261 (78)	280 (84)	289 (56)
IOR	—	32	13	4
Pleasantness				
SRT	291 (34)	231 (32)	231 (44)	223 (49)
IOR	—	60	60	68
Free viewing				
SRT	292 (64)	249 (38)	260 (44)	296 (69)
IOR	—	43	32	−4

Note. Standard deviations are given in parentheses. IOR was calculated by subtracting SRT to probes at previously fixated locations from SRT to probes at novel locations. Negative values are indicative of IOR, whereas positive values are indicative of facilitation in returning to previously fixated locations.

TABLE 2
Mean Number of Fixations and Refixations per Scene and Mean Amount of Time Between Refixations (in Milliseconds) in the Four Task Conditions

Task	Number of fixations	Number of refixations	Time between refixations
Search	26.82 (2.5)	3.37 (0.6)	2,973 (403)
Memory	23.53 (3.23)	4.57 (1.2)	2,552 (156)
Pleasantness	23.66 (2.3)	5.57 (1.6)	2,766 (282)
Free viewing	20.92 (2.7)	4.22 (0.98)	2,584 (219)

Note. Standard deviations are given in parentheses.

slow in detecting two-back and four-back probes (relative to novel probes) in the search condition and not in the other conditions because the probes were further from the current gaze position in the search condition. To address this issue, we calculated the average distance between the probe location and the position of the eye when the probe appeared (Table 3). A mixed ANOVA on the mean distance values, with probe location as a within-subjects factor and task set as a between-subjects factor, yielded an unsurprising main effect of probe location, $F(3, 132) = 21.90$, $p_{rep} = .97$, $\eta_p^2 = .33$. Task set did not have a main effect, and the critical interaction between probe location and task set was not significant, $F(9, 132) < 1$. Thus, the distance between probe position and eye location did not vary as a function of task and could not have caused the differences in IOR among the task conditions.

Though the SRT data suggest that IOR is search-specific, one alternate explanation needs to be ruled out. It has been demonstrated that the bottom-up saliency of objects in a scene can influence saccades (Parkhurst, Law, & Niebur, 2002; Peters, Iyer, Itti, & Koch, 2005). It may be that participants were more likely to fixate salient scene regions during the memory, pleasantness-rating, and free-viewing tasks than during the search task, and this could have caused probes at previously fixated locations to appear at relatively salient locations in the former tasks. To examine this possibility, we used Saliency Toolbox 2.0 (Walther & Koch, 2006) to determine the most salient regions in each of our scenes. Then, for all probes in all conditions, we calculated the saliency of the probe location, as well as the proportion of trials on which the probe appeared in one of the most salient regions. We conducted a mixed ANOVA on the average probe saliency, with probe location as a between-subjects factor and task set as a within-subjects factor. There was a main effect of probe location, $F(3, 132) = 2.85$, $p_{rep} = .93$, $\eta_p^2 = .06$, as average probe saliency was greater at the six-back location than at all other locations (a finding consistent with salient locations being fixated earlier than nonsalient locations; Parkhurst et al., 2002; all p_{rep}s $> .95$), but average saliency did not differ among the other three probe locations. Critically, the interaction between probe location and task set was not significant, $F(9, 132) = 1.23$, $p_{rep} = .65$.

TABLE 3

Mean Distance (in Visual Degrees) of the Eye From the Probe at the Moment of the Probe's Appearance in the Four Task Conditions

	Probe location			
Task	Novel	Two-back	Four-back	Six-back
Search	8.50 (1.2)	6.42 (1.9)	7.73 (2.7)	8.61 (2.0)
Memory	8.64 (0.75)	5.93 (1.7)	7.85 (1.0)	8.53 (1.9)
Pleasantness	8.21 (1.0)	4.80 (2.0)	7.17 (2.5)	7.56 (3.4)
Free viewing	8.95 (1.1)	6.74 (2.4)	8.31 (1.9)	8.98 (2.5)

Note. Standard deviations are given in parentheses.

An analogous ANOVA was performed on the proportion data to determine whether the likelihood of probes occurring in salient regions differed across probe locations and task sets, but no significant main effects or interactions were observed (all Fs < 1). This analysis rules out low-level saliency as a cause of the differences among the task conditions. Consequently, the SRT results are clear: IOR was observed for the search task, but was not observed for any of the nonsearch tasks. Moreover, for the nonsearch tasks, there was an advantage for probes at previously fixated locations compared with probes at unfixated locations, a facilitation-of-return effect that is the reverse of what would be expected if IOR were a general characteristic of visual behavior.

Fixations and Refixations

A careful examination of Table 2 reveals differences in the number of fixations, the number of refixations, and the amount of time between refixations among the task conditions. One-way ANOVAs confirmed an influence of task set on each of these variables, $F(3, 44) = 9.6$, $p_{rep} = .98$; $F(3, 44) = 7.44$, $p_{rep} = .96$; and $F(3, 44) = 5.767$, $p_{rep} = .95$, for fixations, refixations, and time between refixations, respectively. Planned comparisons demonstrated that participants made more fixations in the search condition than in any of the other conditions (all p_{rep}s $>$ .95), made fewer refixations in the search condition than in any of the other conditions (all p_{rep}s $> .95$), and took more time between refixations in the search condition than in any of the other conditions (all p_{rep}s $> .95$). Interestingly, participants took, on average, 3 s between refixations in the search condition, which is also the typically observed temporal limit of IOR (though see Dodd & Pratt, 2007; Tipper, Grison, & Kessler, 2003; and Wilson, Castel, & Pratt, 2006, for evidence of a longer-lasting inhibitory effect). The fact that participants were less likely to refixate objects in the search task than in the nonsearch tasks is consistent with the probe SRT data, and suggests that IOR observed during search does not necessarily extend to nonsearch tasks.

GENERAL DISCUSSION

IOR is often thought of as a general characteristic of visual behavior, despite little to no systematic investigation of this issue. The purpose of this study was to determine whether IOR is observed across a range of visual tasks, or whether it is limited to visual search tasks, in which a bias toward new objects would be beneficial. Participants viewed images of natural scenes, and we probed for the presence of IOR in four task conditions: visual search, memorization, pleasantness rating, and free viewing. Surprisingly, although there was ample evidence that IOR influenced visual search, we observed the opposite pattern of results for all other task sets: Individuals were much faster to look at previously fixated locations than to look at novel locations when doing anything other than search. Previously, researchers have used the term *facilitation of return* to describe a speeded response to a color or orientation target at a previously attended location, and although that effect is different from the one described here, the spirit is quite similar (e.g., Okubo, Mugishima, & Misawa, 2005; Pratt & Castel, 2001; Tanaka & Shimojo, 1996). Moreover, Smith and Henderson (2007, in press) have recently revived the term *facilitation of return* in a series of studies investigating IOR and scene perception, reaching conclusions similar to those we have outlined.

The present data demonstrate that IOR is strongly dependent on the observer's visual task, suggesting that IOR could be a strategic attentional set that operates during visual search tasks. When task performance benefits from a bias toward new objects, as in visual search, IOR is engaged. Presumably, IOR would be observed in nonsearch tasks as well if task performance depended on avoiding previously examined objects and locations (e.g., when counting the number of objects present). In contrast, in tasks that do not depend on a novelty bias, IOR is reversed. These data suggest that the prioritization of previously attended objects is much more flexible than has typically been assumed. Moreover, the consistent observation of facilitation of return in nonsearch tasks suggests that facilitation of return, and not IOR, is actually the default setting of the visual system, with IOR representing an exception implemented during search. However, further research across a broader array of tasks will be required to draw firm conclusions on this issue.

The immediate question, then, is why individuals are faster to return to previously fixated locations than to return to novel locations when they are engaging in nonsearch activities. As previously mentioned, IOR could positively influence performance on memorization or pleasantness-rating tasks if an increase in the number of areas fixated or sampled leads to a more complete memory representation or a better sense of whether a scene is "pleasant." The bias to return to previously attended objects, in contrast, could reflect a number of operations. When trying to create a memory representation of a scene or when determining whether a scene is pleasurable, it could be helpful to return to already viewed locations to determine the spatial relation between items, establish how each item fits into the larger context, encode additional object details, or ensure that initial perceptions and reactions are consistent with overall scene content.

It is less clear, however, why participants were also faster to return to previously fixated locations during the free-viewing task. Previously, Hooge, Over, van Wezel, and Frens (2005) reported evidence that IOR occurs during free viewing. However, Hooge et al. used a different measure of IOR and analyzed each eye movement only as it related to the movement that preceded it. As we discussed earlier, performance on one-back probes is difficult to interpret (given the need to reverse the preceding saccade), and such probes produce mixed results (Klein & MacInnes, 1999). Our multiple dependent measures and multiple probe conditions (two-back, four-back, six-back) provide a more comprehensive assessment of IOR as a function of task set. However, we cannot know with any certainty how each participant conceptualized the free-viewing task. We did ask participants during debriefing how they approached this task, but most participants found this difficult to characterize.

That people are generally faster to return to previously fixated locations than to novel locations in nonsearch tasks would seem to be strong evidence that IOR represents a search-specific strategy. Clearly there is an advantage when searching to visit novel locations, but in other tasks in which the usefulness of this strategy is less apparent, IOR is not observed. Our findings shed considerable light on IOR and visual behavior in general. IOR is clearly not a general characteristic of visually guided behavior. For tasks other than visual search, people are generally faster to return to previously attended or fixated locations than to return to novel locations; the return of attention and gaze to previously fixated locations is facilitated, not inhibited.

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