Research Report

The Left-to-Right Bias in Inhibition of Return Is Due to the Direction of Reading

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ABSTRACT—***Previous research has shown a left-to-right bias in the inhibition-of-return effect. This bias was found in a sample of English-speaking participants who read in a predominantly left-to-right manner. The goal of the current study was to examine the role that the direction of text reading plays in this bias. The findings replicated the left-to-right bias with an English sample, but showed the opposite bias in an Arabic sample, who read text from right to left. Thus, the regularity of shifting attention in a particular way during text reading seems to be the cause of the bias observed.***

The speed with which an organism can search the environment and find a particular target will have a large impact on that organism's ability to survive. One way that search can be made more efficient is to minimize the amount of time that search is directed back to locations that have already been examined. A study by Posner and Cohen (1984) suggested that humans have developed a mechanism that favors the movement of attention toward novel locations. Posner and Cohen found that target detection was slower if a target was presented at the same location as a previous (at least 300 ms prior) sudden onset and offset of a visual stimulus, relative to any other location in the display. Posner, Rafal, Choate, and Vaughan (1985) referred to this finding as inhibition of return (IOR; for a review, see Klein, 2000).

Although the issue is still being debated, most researchers believe that some kind of inhibitory mechanism acting at either the attentional (e.g., Reuter-Lorenz, Jha, & Rosenquist, 1996) or the motor (e.g., Rafal, Calabresi, Brennan, & Sciolto, 1989) level is responsible for this phenomenon. According to these views, once attention leaves a location, inhibition results in a decreased probability of returning to that location. Attentional momentum is an alternative view (Pratt, Spalek, & Bradshaw, 1999). According to this view, attention has associated with it a property akin to the physical property of momentum, such that once attention leaves a location, it would go completely against attention's momentum to return to that location. Therefore, it is faster to go with attention's momentum and continue moving away from the previously attended location.

Why would the attentional system be biased in a manner consistent with momentum? Motion is one of the first things to which infants become sensitive. For example, infants will follow a bar in a moving grating for a short distance and then shift their eyes back to another bar and do this repetitively, a phenomenon referred to as optokinetic nystagmus. This pattern of eye movements is found in infants less than 5 days of age (Kremenitzer, Vaughan, Kurtzberg, & Dowling, 1979), and the absence of optokinetic nystagmus is used as an indicator of neurological problems (Brazelton, Scholl, & Robey, 1966). Tracking an object would be facilitated if the individual could anticipate where that object would move to next. Given that objects in the environment regularly move with momentum, the likely next location for an object would be a location further along its previous path. A bias for attention to move in a manner consistent with object motion (i.e., with momentum) would facilitate the tracking of most objects.

In a previous study (Spalek & Hammad, 2004), we observed two biases in the IOR effect. The first was that the effect was larger when the initial cue was above (resulting in top-to-bottom movement of attention) rather than below (resulting in bottom-to-top movement of attention) the fixation point. Given that objects in the world regularly fall because of gravity, the movement of attention would be more efficient if attention were

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biased toward moving downward. Such an attentional bias could produce the observed top-to-bottom bias in the IOR effect. Thus, there is some support for environmental regularities playing a role in the IOR effect.

The second bias we observed was that IOR was larger when the initial cue was presented to the left (resulting in left-to-right movement of attention) rather than to the right (resulting in right-to-left movement of attention) of the fixation point. In modern life, people are constantly bombarded with written messages from, for example, road signs, advertising, textbooks, and the Internet. Might attention develop a bias that anticipates the occurrence of future information in a direction consistent with text reading? The participants in our study were predominantly English speaking and used to reading text in a left-to-right manner. Therefore, the left-to-right bias observed may have reflected the regularity with which the participants moved their attention to read printed text.

In a study consistent with this interpretation, Pollatsek, Bolozky, Well, and Rayner (1981) found that the shape of the visual attentional field deployed by participants was dependent on the language that they were reading at test. If they were reading English, then the field was asymmetrically expanded to the right. Conversely, if they were reading Hebrew, the field was expanded to the left. In addition, participants typically draw the human figure (Dennis & Raskin, 1960) and the subject of a subject-verb-object relationship (Maass & Russo, 2003) on the side of the page where text writing and reading would originate in their culture. Vaid and Singh (1989) found that the judgment of what affect was depicted in a chimeric face was facilitated when the informative part of the face was on the side where text would originate. Finally, Harsel and Wales (1987) observed improved performance on an inductive reasoning test when the stimuli were arranged in a way consistent with the direction that members of the culture read printed text. Thus, there is mounting evidence that improved performance is observed on a range of tasks when attention starts on the side of the display where text would originate and moves in a direction consistent with text reading and writing. These results suggest that the asymmetry is due not to some innate bias arising from some kind of hemispheric specialization in the attentional system, but rather to a bias that develops as a result of the direction of text reading.

The present study investigated whether the left-to-right bias observed in IOR was due to an innate mechanism or a language-dependent adaptation. If the bias is innate, then target detection should not be affected by the participant's language. If, however, the bias is an adaptation of the attentional system due to the direction of reading, then the bias should be in the direction that the participant's language is read. Specifically, we conducted the IOR experiment in both Egypt, where the primary language (Arabic) is read from right to left, and Canada, where the primary languages are read from left to right. If the direction of reading determines the direction of the bias, then the left-to-right bias expected in the English sample would be reversed for the Egyptian sample.

METHOD

Participants

All participants had normal or corrected-to-normal vision. The Canadian sample ($n = 27$) were fluent in English and were first-year psychology students from the University of Toronto at Scarborough. They participated in this study in exchange for course credit. The Egyptian sample ($n = 20$) were fluent in Arabic and were university students from Alexandria. They volunteered to participate in the experiment in exchange for a pen and thanks for their participation.

Procedure

The presentation of the instructions was the only way in which the experiment differed between the two groups of participants. For the English sample, a set of written instructions was presented on the computer screen. For the Egyptian sample, the instructions were translated to Arabic and presented to participants on paper. In both cases, the instructions were also repeated verbally by the experimenter.

Participants were asked to keep their eyes approximately 30 cm from the computer screen and to keep their eyes on the fixation location for the duration of the experiment. A typical trial sequence is presented in Figure 1. The sequence of events was as follows. A trial commenced with the presentation of two placeholder boxes ($2^\circ \times 2^\circ$ of visual angle) located 10° of visual angle to either side of a "happy face" (included to make the task more appealing to younger participants) at central

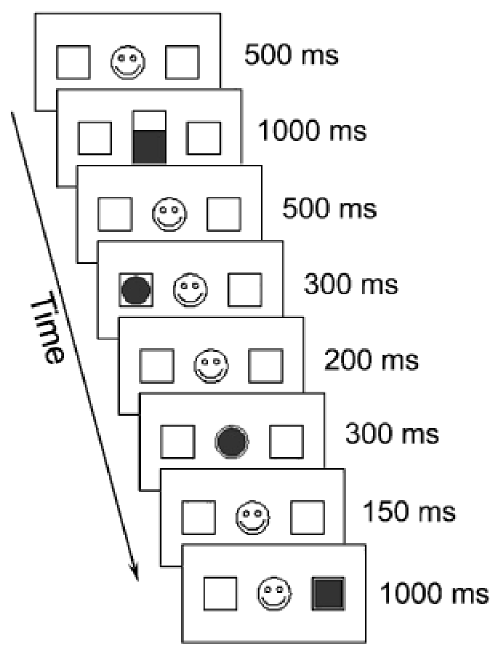

Fig. 1. Sample trial sequence.

fixation. The placeholders served as potential locations for cue and target stimuli. Next, a bar indicating the participant's score appeared at the fixation location. This bar was replaced by the happy face before the experimental sequence began. An initial cue (a filled-in circle with a diameter of 2° of visual angle) then appeared briefly in one of the placeholder boxes, before the same cue stimulus appeared briefly a short time later over the happy face. The sequential presentation of the cue stimuli resulted in a left-to-right or a right-to-left attentional trajectory being established. The target (a filled-in square that was $2^\circ \times 2^\circ$ of visual angle) was then presented in one of the placeholders. The target, like the initial cue stimulus, had an equal probability of occurring in either of the placeholders; the second cue always occurred over the fixation location. The participant's task was to press the space bar as soon as he or she detected the target. Failure to respond within 1,000 ms constituted an incorrect response.

To discourage participants from anticipating the target's presentation, we interspersed catch trials throughout the experiment. A catch trial was the same as the other trials except that no target stimulus was presented. If participants responded by pressing the space bar either on a catch trial or prior to target presentation on a target-present trial, then the trial was coded as an error. Any time an error occurred, an error tone was presented to the participant.

A "current score bar" graphically displayed the participant's score between trials. For every correct detection of a target, a participant's score increased by the difference between the participant's reaction time in milliseconds and 1,000. The score was increased by 500 points if the participant correctly withheld a response during a catch trial, and for each wrong response, the score was reduced by 1,000 points. The purpose of the score bar was to motivate participants to respond quickly and accurately.

Design

The experiment consisted of two blocks of 135 trials separated by a self-paced break. Each block began with 15 practice trials, and the remaining 20 catch trials and 100 target-present trials were presented in a random order. It is important to note that the presentation of the cue stimulus was in no way predictive of the location of the subsequent target, as both the initial cue and the target had an equal probability of occurring at either of the placeholders.

Materials and Apparatus

All visual information was presented on an IBM-compatible laptop computer with a color monitor. Responses were made on the laptop keyboard. The fixation cue was presented centrally on the screen, with placeholders located equidistant from it along the horizontal midline of the display. The program was written in Quick Basic 4.5, with timing routines provided by Graves and Bradley (1987, 1988). Copies of the code are available upon request.

RESULTS AND DISCUSSION

One Egyptian participant's data were excluded from the reaction time analysis because he or she was more than 2.5 standard deviations slower than the rest of the Egyptian participants. The mean reaction times for correct trials (see Table 1) were analyzed using a three-factor mixed-design analysis of variance (ANOVA). Attentional trajectory (direction of the cue presentations: left to right vs. right to left) and relation between the target and initial cue (same side vs. opposite side) served as within-subjects variables; culture (Canadian vs. Egyptian) served as the between-subjects variable.

A main effect of cue-target relation was observed, $F(1, 44) = 106.03$, $\eta_p^2 = .71$, $p < .0001$, with reaction times being slower for targets presented on the same side as the initial cue ($M = 384$ ms) than for targets on the opposite side from the cue ($M = 337$ ms). This result represents the basic IOR effect. There was also a significant three-way interaction among cue-target relation, attentional trajectory, and culture, $F(1, 44) = 10.12$, $\eta_p^2 = .19$, $p = .003$. In the Canadian sample, the IOR effect was significantly larger when the direction of cue presentation was from left to right than when it was from right to left, $F(1, 26) = 5.70$, $\eta_p^2 = .18$, $p = .025$. This finding replicates our previous findings (Spalek & Hammad, 2004). In the Egyptian sample, the IOR effect was significantly larger when the attentional trajectory was from right to left than when it was from left to right, $F(1, 18) = 4.46$, $\eta_p^2 = .20$, $p = .049$. This is opposite to the bias observed in the Canadian sample.

Mean proportions of errors (see Table 1) were analyzed using the same three-factor repeated measures ANOVA as was used for the reaction time results. Only the main effect of culture was significant, $F(1, 44) = 8.00$, $\eta_p^2 = .15$, $p = .007$, with the Egyptian sample making significantly more errors ($M = .024$) than the Canadian sample ($M = .008$).

The results of the present experiment replicated the left-to-right bias in the IOR effect that we observed previously (Spalek & Hammad, 2004). However, this pattern was observed only in the population that read from left to right. In the population that

TABLE 1

Mean Reaction Time (in Milliseconds) and Proportion of Errors (in Parentheses) as a Function of Culture, Relation Between the Initial Cue and Target, and Attentional Trajectory

Culture and attentional trajectory	Cue-target relationship: Same side	Cue-target relationship: Opposite side	Inhibition of return
Canadian	372 (.008)	328 (.007)	45
Left-to-right cue	376 (.009)	325 (.006)	51
Right-to-left cue	369 (.007)	330 (.008)	39
Egyptian	395 (.026)	347 (.022)	48
Left-to-right cue	390 (.030)	348 (.027)	42
Right-to-left cue	400 (.021)	345 (.017)	55

read from right to left, an opposite bias was observed. Although the two samples may have differed on other characteristics, one obvious difference between them was the direction of text reading. Given the directional similarity between the bias and text reading in each of the two cultures, the most parsimonious explanation appears to be that the biases are due to cultural reading regularities and not innate mechanisms. One interesting observation is that the magnitude of the general IOR effect was approximately the same in the two cultures (45 ms for the Canadian sample and 48 ms for the Egyptian sample), and although opposite in sign, the magnitude of the bias was also the same (12 ms for the Canadian sample and 13 ms for the Egyptian sample).

A final point should be made with respect to these data. Although we did not monitor eye position in the present study, Pratt et al. (1999) did monitor eye position in their final two experiments, and the results of all their experiments were consistent with the attentional-momentum view. Given that we assume that both the momentum and the reading-direction bias are the result of environmental regularities, for the sake of parsimony we refer to both as being attentional biases.

GENERAL DISCUSSION

IOR demonstrates that humans have in place a mechanism that promotes the movement of attention toward novel locations while impeding reorientation toward a previously attended location. Attentional momentum is one proposed account of how this novelty bias could be accomplished. According to this view, the attentional system is biased toward moving with momentum because such a bias would result in more efficient tracking of objects. Thus, when attention is set in motion, it tends to keep moving along a given vector of travel until a change is required. The greater the change in direction that is required, the longer the latency to accomplish that change, and this would result in the IOR effect. Therefore, the IOR effect might be due to the attentional system taking advantage of an environmental regularity.

In our previous study (Spalek & Hammad, 2004), we observed two biases associated with the IOR effect: a top-to-bottom bias, which is consistent with a learned regularity associated with objects falling because of gravity, and a left-to-right bias, which could be due to the regularity of the direction in which participants read text. In the present experiment, we tested this reading explanation of the second bias against the idea that the bias is due to some innate bias originating because of hemispheric specialization. The results for the Canadian sample in the present study, along with the results of our previous study (Spalek & Hammad, 2003), which demonstrated a left-to-right bias using an English-speaking (left-to-right reading) sample, are consistent with both explanations. However, the bias reversed in the present experiment when an Arabic (right-to-left reading) sample was tested, and this result is consistent with the text-reading explanation only. Therefore, this study provides additional support for the idea that IOR is due to the attentional system taking advantage of environmental regularities.

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