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Foraging for Thought: An Inhibition-of-Return-Like Effect Resulting From Directing Attention Within Working Memory

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Abstract
Perceptual processing of a target stimulus may be inhibited if its location has just been cued, a phenomenon of spatial attention known as *inhibition of return* (IOR). In the research reported here, we demonstrated a striking effect, wherein items that have just been the focus of reflective attention (internal attention to an active representation) also are inhibited. Participants saw two items, followed by a cue to think back to (i.e., *refresh*, or direct reflective attention toward) one item, and then had to identify either the refreshed item, the unrefreshed item, or a novel item. Responses were significantly slower for refreshed items than for unrefreshed items, although refreshed items were better remembered on a later memory test. Control experiments in which we replaced the refresh event with a second presentation of one of the words did not show similar effects. These results suggest that reflective attention can produce an inhibition effect for attended items that may be analogous to IOR effects in perceptual attention.

Keywords
short-term memory, attention, memory, refreshing

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Adequately processing the flood of incoming information bombarding the senses would be impossible without a selection mechanism—attention—to restrict the flow. Given the large number of studies of perceptual attention, it is perhaps natural to associate attention with sensory processing, particularly vision. However, just as one cannot simultaneously examine every stimulus in the visual field, it is impossible to simultaneously think every thought that a situation might trigger. Psychologists dating back to William James (1890) have noted that attention must operate within both the external-perceptual and internal-reflective domains (e.g., M. K. Johnson et al., 2005). Yet studies comparing perceptual and reflective attention are still few compared with the many studies of perceptual attention alone, and the extent to which phenomena and mechanisms of perceptual attention also operate within, or have homologues or analogues in, the reflective domain of thought and memory is still relatively unknown (for review, see Chun, Golomb, & Turk-Browne, 2011; Chun & Johnson, 2011; Lepsien & Nobre, 2006).

One such perceptual-attention phenomenon is *inhibition of return* (IOR; Posner & Cohen, 1984; Posner, Rafal, Choate, & Vaughan, 1985). IOR is characterized by slower responses to a stimulus presented at a location where an attention-capturing cue was presented several hundred milliseconds earlier, compared with a stimulus presented at an uncued location. This inhibition of orienting to previously attended locations has been proposed to facilitate

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"foraging" for novel information to aid visual search or more efficiently explore visual environments (Klein, 2000; Klein & MacInnes, 1999).

One might therefore propose that an IOR-like mechanism could facilitate thought as well as perception. Such a mechanism could encourage foraging among thoughts, preventing perseveration on single ideas, potentially enhancing creativity, and keeping the stream of consciousness flowing. To test whether an IOR-like phenomenon might occur in reflection, we examined a simple reflective-attention process that is a close analogue to perceptual selective attention.

Refreshing is the act of thinking back to and foregrounding an active mental representation (e.g., of a just-presented stimulus; Chen & Cowan, 2009; Higgins & Johnson, 2009; M. K. Johnson et al., 2005; M. K. Johnson, Reeder, Raye, & Mitchell, 2002; Raye, Johnson, Mitchell, Reeder, & Greene, 2002). Refreshing shares some neural characteristics with perceptual attention. For example, refreshing and perceptual attention activate a similar, partially overlapping frontoparietal network, and both can modulate activity in visual cortical areas relevant to the target item (M. R. Johnson & Johnson, 2009; M. R. Johnson, Mitchell, Raye, D'Esposito, & Johnson, 2007; Lepsien & Nobre, 2007; Roth, Johnson, Raye, & Constable, 2009).

As noted, perceptual attention can either inhibit or facilitate target responses, depending on the circumstances of the task. Similarly, refreshing can have both positive and negative effects. Refreshing can increase long-term memory for refreshed items relative to unrefreshed items (e.g., M. K. Johnson et al., 2002) and produce repetition attenuation in visual cortex for later presentations of refreshed items (Yi, Turk-Browne, Chun, & Johnson, 2008). However, refreshing also can reduce short-term reflective and perceptual access to unrefreshed items (Higgins & Johnson, 2009). Higgins and Johnson (2009) did not test the effects of refreshing on immediate access to the refreshed items themselves, so their results do not speak to whether an IOR-like mechanism could temporarily reduce the accessibility of refreshed representations. In the present study, we sought to examine the impact of reflective attention on subsequent perception of both refreshed and unrefreshed items.

Experiment 1

Method

Nine paid participants (7 female, 2 male; mean age = 21.3 years) from Yale University took part in Experiment 1a. An additional 20 participants (12 male, 8 female; mean age = 19.2 years) from Ohio State University (OSU) took part in Experiment 1b in return for course credit. Procedures for all experiments were approved by the institutional review boards of both universities.

In the main task (Fig. 1a), two words, which participants were instructed to read silently, were presented onscreen for 1,500 ms, followed by a brief blank-screen delay (500 ms) and then an arrow pointing to the location of one of the two just-presented words (1,500 ms). The arrow cued participants to think back to the indicated word and to say it aloud. At 100 ms after the arrow's offset, participants saw a final word (1,500 ms): the refreshed word (*refreshed-probe condition*), the word that was initially presented but not refreshed (*unrefreshed-probe condition*), or a novel word (*novel-probe condition*). Participants were instructed to read the word aloud as quickly and as accurately as possible. The intertrial interval was 3,000 ms.

The task comprised 144 trials (48 per condition). Stimulus lists were equated (all *p*s > .8) for word length, frequency, number of phonemes, number of syllables, and average time to read aloud (Balota et al., 2007); all conditions and lists were fully counterbalanced across participants. Responses were spoken into a microphone and recorded digitally. The digital recording was analyzed using a custom MATLAB (The MathWorks, Natick, MA) script that detected sounds exceeding a specified amplitude and duration (generally half the standard deviation of the entire recording's amplitude for at least 100 ms) and allowed manual adjustment of the word onset if automatic word detection failed or was triggered early by nonspeech sounds. Some recordings with excessive low-frequency background noise were high-pass filtered before processing (cutoff frequency = 100 Hz). Trials on which participants misspoke, stammered, or spoke too quietly for their response to be detected were discarded (Experiment 1a: 2.9% of trials; Experiment 1b: 8.9% of trials).

After the main task, participants in Experiment 1a performed an unrelated working memory task with letters of the alphabet for approximately 20 min before receiving a surprise memory test. (Participants in Experiment 1b performed only the main task.) All 336 words presented in the main task were pseudorandomly intermixed with 336 foil words (672 trials total). The memory test included four main item types: refreshed words, unrefreshed words, target words, and foils. These types can be further subdivided by which condition of the main task they originally appeared in. Refreshed words could be presented again as probes (in the refreshed-probe condition) or not (in either the unrefreshed-probe condition or the novel-probe condition). Likewise, unrefreshed words could occur as probes (in the unrefreshed-probe condition) or not (in the refreshed-probe condition or the novel-probe conditions). Novel words were seen only in the novel-probe condition.

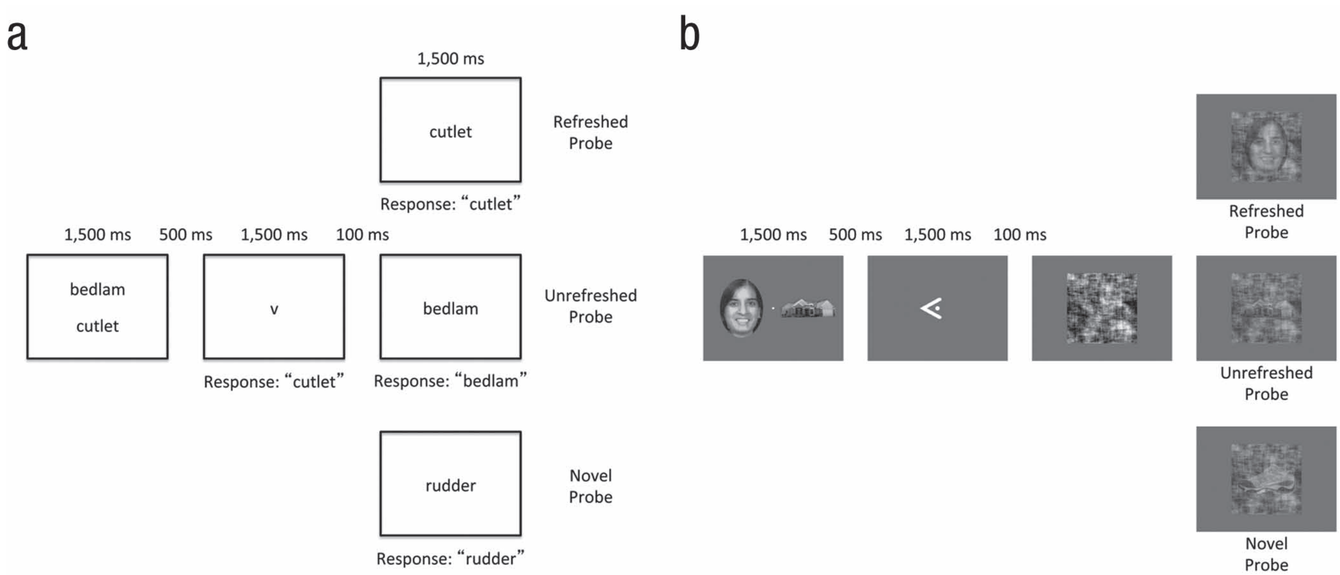

Fig. 1. Task diagrams. In Experiment 1 (a), participants first saw two words, followed by an arrow cue instructing them to think back to (i.e., refresh) one of the just-presented words and speak it aloud. After that, a probe word was presented, and participants were instructed to speak it aloud as quickly and accurately as possible. Probes could be a re-presentation of the refreshed word (refreshed probe), a re-presentation of the unrefreshed word (unrefreshed probe), or a novel word (novel probe). The design of Experiment 2 was similar to that of Experiment 1, except that instead of an arrow cue, one of the initial words was simply re-presented on-screen for participants to read aloud. In Experiment 3 (b), participants first saw two pictures, followed by an arrow cue instructing them to briefly visualize (i.e., refresh) one of the just-presented pictures. A series of scrambled noise images then appeared and gradually faded away to reveal the refreshed item (refreshed probe), the unrefreshed item (unrefreshed probe), or a novel item (novel probe). Participants were instructed to press a "stop" button as soon as they detected the probe picture underneath the noise.

On each test trial, a word was presented centrally along with the question "Have you seen this word before?" Participants answered "definitely no," "maybe no," "maybe yes," or "definitely yes" by pressing one of four keys. Responses were converted into numerical confidence ratings ranging from 1 (confident the item was new) to 4 (confident the item was old).

Results

A one-way repeated measures analysis of variance (ANOVA) of response times (RTs) for probes in the three conditions (Fig. 2a) was significant in both Experiment 1a, $F(2, 16) = 49.05$, $p < 10^{-6}$, $\eta_p^2 = .86$, and Experiment 1b, $F(2, 38) = 90.62$, $p < 10^{-14}$, $\eta_p^2 = .83$. Paired t tests between all pairs of conditions also were significant in both experiments (all individual ps < .002). Participants responded more slowly to novel probes (Experiment 1a: mean RT = 567 ms; Experiment 1b: mean RT = 513 ms) than to probes that had appeared in the initial display (whether refreshed or unrefreshed) and responded more slowly to refreshed probes (Experiment 1a: mean RT = 511 ms; Experiment 1b: mean RT = 463 ms) than to unrefreshed probes (Experiment 1a: mean RT = 488 ms; Experiment 1b: mean RT = 438 ms). One might expect items that had just been refreshed and spoken aloud to be more strongly activated and, thus, show a stronger priming effect (faster RTs); the presence of the reverse pattern, by contrast, suggests an effect of reflective attention analogous to IOR.

In contrast, the long-term memory test in Experiment 1a showed an advantage for refreshed items over unrefreshed items (Fig. 2c). All types of old items had higher confidence ratings (i.e., they were better remembered) than foils, all individual ts(8) > 6.4, ps < .0002 (two-tailed paired t tests). In addition, probed items (collapsed across refreshed, unrefreshed, and novel probes) were remembered better than were nonprobed items (collapsed across condition), $t(8) = 5.86$, $p < .0005$.

However, to test the primary hypothesis regarding the effects of refreshing, we conducted a 2 (refreshed vs. unrefreshed words) × 2 (probed vs. nonprobed words) repeated measures ANOVA, collapsing nonprobed words across relevant conditions (e.g., refreshed nonprobed words appeared on trials in which the probe was either novel or the unrefreshed item; unrefreshed nonprobed words appeared on trials in which the probe was either novel or the refreshed item). The ANOVA showed significant main effects of refreshing, $F(1, 8) = 26.16$, $p < .001$, $\eta_p^2 = .77$, and probe status, $F(1, 8) = 25.91$, $p < .001$, $\eta_p^2 = .76$. Planned comparisons indicated that refreshed items were remembered better than unrefreshed items for both probed words, $t(8) = 2.79$, $p < .03$, and nonprobed words, $t(8) = 4.10$, $p < .005$. There also was an

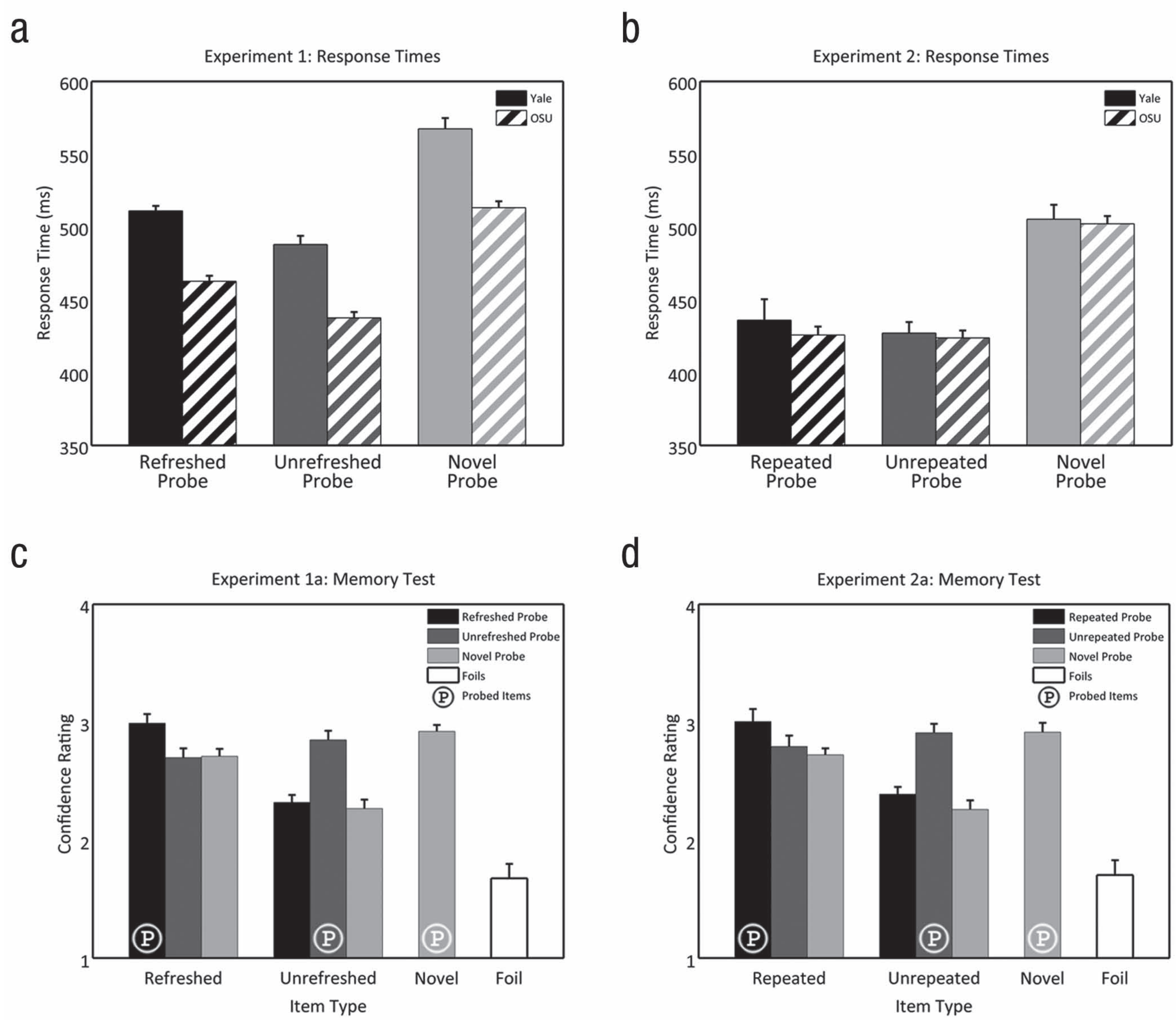

Fig. 2. Results from Experiments 1 and 2. The top graphs show response times as a function of condition and group (participants from Yale or from Ohio State University, OSU) in Experiment 1 (a) and Experiment 2 (b). The bottom graphs show ratings of confidence for memory-test items as a function of item type and condition in Experiment 1a (c) and Experiment 2a (d). Confidence ratings could range from 1 to 4, with higher scores indicating greater confidence. Error bars in all panels were generated using Morey's (2008) correction to Cousineau's (2005) method for creating intuition-fitting error bars for within-subjects comparisons.

interaction of probe status and refreshing, $F(1, 8) = 5.40$, $p < .05$, which was due to a greater benefit of refreshing for nonprobed words than for probed words. Confidence ratings for novel probes were numerically between those for refreshed probes and for unrefreshed probes but not significantly different from either ($p = .33$ and $p = .28$, respectively).

Experiment 2

Experiment 2 was designed to confirm that the results of Experiment 1 were due to reflective attention and not merely the consequence of participants' having said one word aloud (i.e., the refreshed word) but not the other (i.e., the unrefreshed word).

Method

Nine paid participants (all female; mean age = 21.7 years) from Yale took part in Experiment 2a. An additional 21 participants (12 male, 9 female; mean age = 18.7 years) from OSU took part in Experiment 2b in return for course credit. The design was identical to that of Experiment 1 except for one critical change: In the main task, instead of an arrow cuing participants to refresh a just-presented word and say it aloud, the word itself was presented on-screen. The duration of the second event (in this case, the repeated word) was reduced from 1,500 ms to 1,300 ms, and the delay between the second event and the probe was increased from 100 ms to 300 ms to make the transition between the repeated word and the probe more obvious while keeping all stimulus-onset asynchronies (SOAs) identical to those in Experiment 1. Participants were instructed to read the initial pair of words silently to themselves and then to read aloud the two subsequently presented words as quickly and accurately as possible. The same stimulus lists and equipment were used as in Experiment 1. The analogue of Experiment 1's refreshed-probe condition was the repeated-probe condition, and the analogue of Experiment 1's unrefreshed-probe condition was the unrepeated-probe condition. Participants in Experiment 2a performed the same retention-interval filler task and memory test used in Experiment 1a; participants in Experiment 2b performed only the main task. In total, 5.0% of trials were discarded in Experiment 2a, and 6.8% were discarded in Experiment 2b.

Results

A one-way repeated measures ANOVA of probe RTs for the three conditions (Fig. 2b) was significant in both Experiment 2a, $F(2, 16) = 15.17$, $p < .0005$, $\eta_p^2 = .66$, and Experiment 2b, $F(2, 40) = 68.63$, $p < 10^{-12}$, $\eta_p^2 = .77$. Paired *t* tests showed that the significant ANOVA result was due only to repeated and unrepeated probes' being faster than novel probes (Experiment 2a: mean RT = 505 ms; Experiment 2b: mean RT = 502 ms)—repeated probes, Experiment 2a (mean RT = 436 ms): $t(8) = 3.61$, $p < .01$; repeated probes, Experiment 2b (mean RT = 426 ms): $t(20) = 9.52$, $p < 10^{-8}$; unrepeated probes, Experiment 2a (mean RT = 427 ms): $t(8) = 9.16$, $p < .0001$; unrepeated probes, Experiment 2b (mean RT = 424 ms): $t(20) = 11.11$, $p < 10^{-9}$. Critically, RTs for the repeated-probe and unrepeated-probe conditions did not differ (Experiment 2a: $p = .61$; Experiment 2b: $p = .80$). This pattern of results indicates that merely saying a word aloud is insufficient to induce an IOR-like effect and suggests that the effect observed in Experiment 1 indeed resulted from reflective attention. To confirm this difference between Experiments 1 and 2, we combined data from the Yale and OSU participant groups and performed a mixed 2 (experiment: 1 vs. 2) × 2 (condition: refreshed/repeated vs. unrefreshed/unrepeated) ANOVA. The critical interaction between experiment and condition was significant, $F(1, 57) = 6.03$, $p < .02$, $\eta_p^2 = .10$, which confirmed the difference between the two experiments and suggested that the lack of an IOR-like effect in Experiment 2 was unlikely to result from insufficient statistical power.

We also performed a three-way ANOVA with the additional factor of group (Yale vs. OSU) to determine whether it was appropriate to combine the two groups. There was no significant interaction with group (all *p*s > .19) and only a weak trend for a main effect ($p = .09$), such that OSU participants responded somewhat faster than Yale participants overall. Thus, we felt it was appropriate to combine the groups. However, the critical interaction was also significant in the larger OSU sample alone, $F(1, 39) = 6.00$, $p < .02$, $\eta_p^2 = .13$.

As expected, Experiment 2a's memory-test results (Fig. 2d) were similar to those of Experiment 1a. Old items had higher confidence ratings than did foils, all individual ts$(8) > 5.7$, ps $< .0005$; and probed items were remembered better than were nonprobed items, $t(8) = 5.95$, $p < .0005$. Furthermore, the 2 (repetition condition: repeated vs. unrepeated) × 2 (probe status: probed vs. nonprobed) repeated measures ANOVA showed main effects of repetition, $F(1, 8) = 14.48$, $p < .006$, $\eta_p^2 = .64$, and probe status, $F(1, 8) = 25.86$, $p < .001$, $\eta_p^2 = .76$, and a significant interaction, $F(1, 8) = 5.71$, $p < .05$, $\eta_p^2 = .42$, with a greater benefit of repetition for nonprobed words than for probed words; all of these effects were analogous to those in Experiment 1a. Planned comparisons showed that repeated items were remembered significantly better than unrepeated items for nonprobed words, $t(8) = 4.51$, $p < .002$, and were numerically but not significantly better for probed words, $p = .38$. The similar memory-test results again suggested that the lack of an IOR-like RT effect for repeated items was not due to insufficient power or reduced attention in Experiment 2.

Experiment 3

In Experiment 3, we tested whether the effects seen in Experiment 1 also occurred for nonword stimuli.

Method

Twenty-two paid participants (17 female, 5 male; mean age = 20.9 years) from Yale took part in Experiment 3a. An additional 29 participants (19 female, 10 male; mean age = 19.6 years) from OSU took part in Experiment 3b in return for course credit; 1 other participant was excluded as an outlier for having overall RTs more than 3 standard deviations above the group mean.

The task (Fig. 1b) was conceptually similar to the main task in Experiment 1 except that it used different materials and a different probe measure. Participants first saw two pictures (drawn from a set of chair, face, house, and shoe stimuli; Newman & Norman, 2010) presented side by side for 1,500 ms, followed by a 500-ms delay, and then the presentation of an arrow pointing to the location of one of the just-presented items for 1,500 ms. The arrow cued participants to think back to the indicated item and briefly visualize it. At 100 ms after the arrow's offset, a series of noise images (formed by phase scrambling pieces of randomly selected picture stimuli) flashed onscreen at 30 Hz. A probe image faded into view underneath the changing noise images (starting at 10% opacity and fading in at the rate of 60% opacity per second); probes could be either the refreshed picture (refreshed-probe condition), the picture that was initially presented but not refreshed (unrefreshed-probe condition), or a novel picture (novel-probe condition). Participants were instructed to press a "stop" button with their nondominant index finger as soon as they detected the probe picture. When they did, the probe display disappeared and a display appeared asking them whether the probe was a chair, a face, a house, or a shoe. Participants indicated the category using one of the four nonthumb fingers of their dominant hand.

The task comprised 216 trials (72 per condition) divided into three blocks. The initial presentation was always of two pictures from different categories (e.g., a chair and a face or a chair and a shoe, but never two chairs), and in the novel-probe condition, the probe's category was always different from that of both the refreshed and the unrefreshed stimuli. Each block contained equal distributions of each stimulus category in every position; trial orders and the stimuli seen on each trial were randomized without replacement. Participants were instructed to maintain central fixation between the onset of the initial stimulus pair and the offset of the probe display. RTs were measured from the onset of the noise images to the participant's press of the "stop" button. Trials on which participants incorrectly identified the probe category were discarded (Experiment 3a: 2.3%; Experiment 3b: 2.1%). No memory test was administered.

Results

A one-way repeated measures ANOVA of probe RTs for the three conditions (Fig. 3a) was significant in both Experiment 3a, $F(2, 42) = 15.50$, $p < 10^{-5}$, $\eta_p^2 = .42$, and Experiment 3b, $F(2, 56) = 6.24$, $p < .005$, $\eta_p^2 = .18$. Paired *t* tests between all pairs of conditions also were significant (all individual *p*s < .05), with the exception of unrefreshed and novel probes in Experiment 3b, $t(28) = 1.45$, $p = .16$. Responses were fastest for novel probes (Experiment 3a: mean RT = 1,046 ms; Experiment 3b: mean RT = 1,022 ms), followed by unrefreshed probes (Experiment 3a: mean RT = 1,053 ms; Experiment 3b: mean RT = 1,026 ms), and were slowest for refreshed probes (Experiment 3a: mean RT = 1,069 ms; Experiment 3b: mean RT = 1,033 ms). Thus, the same IOR-like effect (slower responses to refreshed than to unrefreshed probes) was seen as in Experiment 1. The fact that in Experiment 3, RTs were fastest for novel probes, whereas in Experiment 1, they were slowest for novel probes, may have resulted from the difference in stimulus category (pictures vs. words), the difference in probe type (button press vs. verbal response), or a combination of these factors. The last possibility seems particularly likely because the verbal responses (reading the probe word aloud) in Experiments 1 and 2 were likely primed by participants' previously seeing the refreshed and unrefreshed words, whereas in Experiment 3, the time-critical response

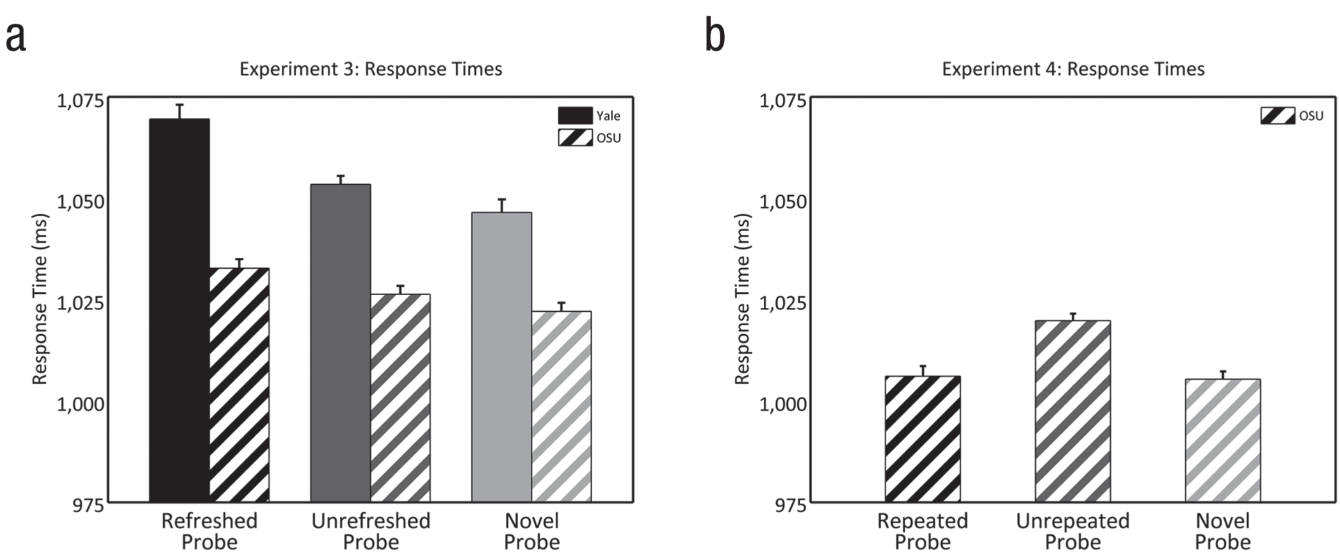

Fig. 3. Results from Experiments 3 and 4. The graph in (a) shows response times as a function of condition and group (participants at Yale or at Ohio State University, OSU) in Experiment 3. The graph in (b) shows response times as a function of condition in Experiment 4 (all participants in Experiment 4 were from OSU). Error bars in all panels were generated using Morey's (2008) correction to Cousineau's (2005) method for creating intuition-fitting error bars for within-subjects comparisons.

(pressing the "stop" button) was the same across all conditions and, thus, unlikely to have been primed by previously seen stimuli.

Experiment 4

As Experiment 2 did for Experiment 1, Experiment 4 tested whether Experiment 3's IOR-like effect was indeed specific to the case of reflective attention and could not be induced simply by a perceptual re-presentation of a stimulus.

Method

Twenty-nine undergraduates from OSU (18 male, 11 female; mean age = 19.7 years) participated in Experiment 4 in return for course credit; 1 additional participant was excluded as an outlier for having overall RTs more than 3 standard deviations above the group mean. The design was identical to that of Experiment 3 except that instead of an arrow cuing participants to refresh one just-presented picture, the picture itself was shown on-screen. Participants were instructed simply to view and pay attention to the presented pictures and then respond to the probe stimulus, as in Experiment 3. The same stimuli, timings, and equipment were used as in Experiment 3b. Error trials (2.0%) were again discarded.

Results

A one-way repeated measures ANOVA of probe RTs for the three conditions (Fig. 3b) was significant, $F(2, 56) = 15.13$, $p < 10^{-5}$, $\eta_p^2 = .35$. Paired *t* tests showed that in the critical comparison between repeated probes (mean RT = 1,006 ms) and unrepeated probes (mean RT = 1,020 ms), participants actually responded faster to repeated probes, $t(28) = 4.29$, $p < .0005$. Participants also responded faster to novel probes (mean RT = 1,005 ms) than to unrepeated probes, $t(28) = 6.55$, $p < 10^{-6}$, and RTs did not differ between repeated and novel probes, $p = .83$. These results suggested once again that mere perceptual repetition was insufficient to drive the IOR-like effect observed in Experiment 3; in fact, the opposite effect was observed in Experiment 4.

To confirm the difference between Experiments 3 and 4, we combined the Experiment 3a and 3b participant groups and performed a mixed 2 (experiment: 3 vs. 4) × 2 (condition: refreshed/repeated or unrefreshed/unrepeated) ANOVA. The critical interaction between experiment and condition was significant, $F(1, 78) = 35.16$, $p < 10^{-7}$, $\eta_p^2 = .31$. This interaction confirmed the difference between the results of Experiments 3 and 4 and, coupled with the fact that participants responded significantly more slowly to unrepeated than to repeated probes in Experiment 4, suggests again that the lack of an IOR-like effect in Experiment 4 was not due to insufficient statistical power or participants' failure to attend to the task. Because Experiment 4 was conducted only at OSU, we could not run a three-way ANOVA to determine whether group (Yale vs. OSU) affected the interaction; however, the interaction was also significant in the OSU sample alone, $F(1, 56) = 20.77$, $p < .0001$, $\eta_p^2 = .27$.

Discussion

The results from these studies demonstrate that participants were slower to respond to a word (Experiment 1) or a picture (Experiment 3) that was recently the target of internal (reflective) attention than to a word or picture that was not. This effect did not occur when words or pictures were simply shown again, without participants reflectively accessing an active memory representation (Experiments 2 and 4).

This apparent short-term inaccessibility of recently refreshed representations stands in contrast to the long-term memory benefit we observed for refreshed words compared with unrefreshed words (Experiment 1a), which replicated previous findings of better memory for refreshed items compared with unrefreshed items (e.g., M. K. Johnson et al., 2002). Thus, whatever mechanisms underlie the impairment in responding to refreshed items at the short-term (~1 s) timescale do not persist forever but eventually (by ~20 min later, in this study) cross over into a long-term memory benefit. Of course, the differences in timescale and task (the implicit initial probe vs. a later explicit recognition test) make it difficult to directly compare short-term impairment with long-term facilitation; thus, in future studies, researchers may find it helpful to employ, together or individually, a more implicit long-term test and a shorter retention interval in order to investigate the transition from impairment to facilitation more fully.

This short-term negative impact on identifying an item whose representation was recently the target of (and was presumably enhanced by) reflective attention invites a comparison to the short-term IOR caused by visuospatial attention. To our knowledge, no such effect has been reported in the IOR literature or other areas of cognitive psychology. Fuentes, Vivas, and Humphreys (1999) reported a somewhat similar "semantic-IOR" effect for words, but that effect differed from the IOR-like effects we observed in two critical ways. First, the Fuentes et al. design involved only perception of the items in question, without a reflective-attention cue, whereas our Experiment 2 showed that perceptual repetition without reflective attention did not produce the same IOR-like effect we observed in Experiment 1. Second, Weger and Inhoff (2006) demonstrated that the semantic IOR effect found by Fuentes et al. depended on extensive item repetition and a small, homogenous set of items, whereas our IOR-like effects were observed using unique, heterogeneous stimulus sets.

Although both the present effect and traditional IOR effects share the characteristic of slowed responses to an item or location that was recently the focus of attention, the two effects may or may not be mechanistically related. Future studies (e.g., studies using neuroimaging) will be necessary to establish whether the two effects stem from a common neural source, whether they result from a similar neural phenomenon (e.g., habituation) occurring at distinct loci, or whether their underlying neural sources are unrelated. Complicating interpretation of the present study is that even traditional IOR is not completely understood; it may arise as a result of activity at multiple levels of the nervous system, and deciding which effects should even be labeled as IOR is subject to debate (for review, see Dukewich, 2009). Thus, *IOR* may be a descriptor for a class of perceptual- and reflective-attention effects with varying degrees of similarity in their neural or behavioral profiles; alternatively, evidence may arise for a qualitative distinction between "true" IOR and other effects.

Either way, additional studies manipulating the SOA of the probe would help characterize our reflective IOR-like effect in relation to traditional IOR effects. Spatial IOR typically begins from 200 to 300 ms after the initial cue and may persist for several seconds (Klein, 2000), with attentional facilitation occurring at shorter SOAs. Although reflective attention can enhance active neural representations in a manner similar to perceptual-attentional enhancement (M. R. Johnson & Johnson, 2009), it is unknown whether reflective attention would similarly facilitate behavioral responses to refreshed stimuli at shorter SOAs before IOR-like effects begin. If demonstrated, such a pattern of facilitation at very short time spans (less than 250 ms) followed by inhibition would support the idea that traditional IOR and our reflective IOR-like effect stem from similar cognitive mechanisms. A related possibility is that IOR's general pattern of facilitation followed by later inhibition may occur for reflective attention, but on a slower timescale, because of differences between exogenously cued perceptual attention and endogenously cued reflective attention. The timing of endogenous reflective-attention events is likely to be more variable than that of exogenous perceptual-attention events as well; thus, high-temporal-resolution recording methods, such as electroencephalography, could be helpful not only for describing the general neural profile of reflective IOR-like effects but also for determining the onsets of internal mental events in order to time lock probe presentations more precisely relative to them.

Demonstrating facilitation at shorter delays would certainly strengthen the analogy between traditional IOR and the IOR-like slowing we report here, but even if such facilitation does not emerge in future studies, the strong inhibition of subsequent probe processing we have observed for instances of reflective attention (but not perceptual repetition) is nonetheless a striking and noteworthy effect deserving of additional study. Thus, in either event, further investigations of these possibilities should provide a more fine-grained understanding of IOR-like response slowing in both the reflective and the traditional perceptual domains, as well as shed further light on the relationship and possible overlap between the neurocognitive processes comprising reflective and perceptual attention.

Declaration of Conflicting Interests

The authors declared that they had no conflicts of interest with respect to their authorship or the publication of this article.

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