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Semantic inhibition of return is the exception rather than the rule

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Abstract

Inhibition of return (IOR) has recently been reported for lexical/semantic categories (see, e.g., Fuentes, Vivas, & Humphreys, 1999). The present research examines the impact on semantic IOR of three components: item repetition, item heterogeneity, and spatial variability. Experiments 1 and 2 indicate that lexical/semantic IOR occurs only after extensive repetition. Experiment 2 also shows that semantic IOR is independent of spatial variability. Experiments 3 through 5 show facilitatory rather than inhibitory effects when the item pool is heterogeneous. The results support an episodic account of semantic IOR, according to which inhibitory effects accumulate with massive repetition of homogeneous items.

The orienting of attention is an integral part of human information processing, and its mechanisms have been widely studied throughout past decades. In the spatial cuing paradigm (Posner, 1980), a target stimulus is preceded by either a valid or an invalid cue. In this paradigm, orienting of attention toward a peripheral location shows a biphasic time course: After the onset of a valid cue, detection of a subsequent target stimulus is facilitated at this location for a brief period. After this initial facilitation, however, an inhibitory phase emerges, starting at about 300 msec; now, target detection at the cued location is slowed when compared with target detection at the uncued location, a phenomenon that has since been referred to as inhibition of return (IOR; Posner & Cohen, 1984; Posner, Rafal, Choate, & Vaughan, 1985).

The term *inhibition of return* is based on the assumption that for IOR to occur, attention is initially directed to the cued location in the periphery and then pulled away to the central fixation location before the subsequent target is presented at the cued location in the periphery. The cued location will be indexed as previously attended, and attention will be biased to not refocus on that location for a brief period. It has been argued that such a tagging mechanism bears some adaptive value, because it biases attention toward novelty in a situation in which resources would otherwise be wasted if individual tokens were attended to multiple times (Klein, 2000).

The studies following the seminal work by Posner and Cohen (1984) have revealed important findings about the mechanisms underlying IOR. It is now known that multiple locations can be inhibited (see, e.g., Snyder & Kingstone, 2000), and that IOR can even extend across a full quadrant of the visual hemifield, even when only one specific spot has been cued (Bennett & Pratt, 2001). Moreover, whereas early approaches have focused mainly on the spatial dimension of IOR, more recent evidence points toward other types of IOR, suggesting that it is a more general attentional-gating mechanism.

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Inhibition of Return in Nonspatial Dimensions

Some evidence outside the spatial domain comes from studies that dissociate cuing validity and spatial location of the cue. In an early series of experiments, Tipper, Driver, and Weaver (1991) showed a pair of two peripheral boxes, one of which served as a cue. Following the cue, the boxes discretely rotated halfway across the screen before the target appeared in either the cued or the uncued box. The apparent motion was achieved by presenting the boxes in a series of short frames. Reaction times (RTs) in response to the cued box were slower in comparison with RTs for the uncued box even when the cued box was in the location of the previously uncued one, in what was called the 180° rotation condition. Even though these experiments involved spatial change, they also show that some aspect of IOR extends beyond the spatial dimension: The cuing of a location usually implies the cuing of an object, and vice versa. Specifically, the study by Tipper et al. (1991) suggests that the cuing in the 180° rotation condition was effective because the box (the “object”) was cued, rather than its location. The phenomenon, later labeled *object-based IOR*, is highly robust and has been replicated many times (see, e.g., Jordan & Tipper, 1998; Leek, Reppa, & Tipper, 2003; McCarley, Kramer, & Peterson, 2002; but see Müller & von Mühlenen, 1996, for an opposing view).

It has also been observed—even further removed from the original spatial domain—that IOR may occur for color perception. In a series of experiments, Law, Pratt, and Abrams (1995) showed that participants were slower to respond to a color patch if that same patch had been shown earlier at the same location. The effect emerged only when both the prime and the target stimuli were separated by an intervening patch with a neutral color, mimicking the central fixation that serves to disengage attention from the peripheral location in the spatial domain. Other research has extended the phenomenon to auditory orienting (see, e.g., Mondor, Breau, & Milliken, 1998). Mondor and Lacey (2001) provided evidence of duration-, intensity-, and timbre-based auditory IOR, none of which involved a spatial dimension. Tipper, Grison, and Kessler (2003) observed IOR in the context of face identification, and results by Francis and Milliken (2003) suggest that IOR occurs in the context of studies relating to the length of a line.

All of the studies discussed so far involved a *perceptual* identification or classification (either visual or auditory), but IOR has also been examined for symbolic objects, such as visual words. Chasteen and Pratt (1999), for instance, used a design in which two boxes were shown, one above and one below a central fixation cross. One of the boxes darkened briefly, serving as the cue; following this, the central fixation dot was briefly illuminated and then a letter string appeared in either the cued or the uncued box. Participants had to decide whether the target was a word or not (Experiment 1) or whether it denoted a person or an object (Experiment 2). Both lexical and categorical classification times were longer for the cued as opposed to the uncued location. Before concluding that these results reveal lexical IOR, one needs to bear in mind that the relation between the cue and the target was exclusively spatial in both experiments: The cue was the darkening of a *peripheral* box, either at the same location or at a location other than where the subsequent target would appear. The same results could have emerged if any other type of response had been required—for instance, if participants had been asked to simply detect the onset of an item, regardless of whether it was a word or a nonword.[1] In order for lexical/semantic IOR to occur, the relationship between the cue and the target must be exclusively lexical/semantic; in this instance, both a lexical and a spatial component were involved.

[1]In their experiments, Chasteen and Pratt (1999) also found differential degrees of inhibition for high- and low-frequency words and for non-words. However, this still does not provide evidence that the inhibitory effect is located on a lexical level, because differential degrees of IOR may also be found in simple detection responses, in which the degree of stimulus complexity is varied.

In a recent series of experiments, Fuentes, Vivas, and Humphreys (1999) employed a paradigm that allowed them to test semantic IOR. A prime word (e.g., *dog*) was followed by an unrelated intervening stimulus (e.g., *sea*) and a subsequent stimulus that was either related to the original category (e.g., *cat*) or unrelated to that category (e.g., *finger*). Target words were interspersed with target nonwords, and lexical decision times were obtained. Under these conditions, Fuentes et al. (1999) found that responses were made more quickly to unrelated than to related targets when the intervening stimulus belonged to a new category (and shifted attention away from the primed category), whereas the opposite effect was found when attention was not disengaged from the original (primed) category. The authors interpret this as a semantic equivalent to spatial IOR: "The results [. . .] are important because they show, in the semantic domain, an inhibitory effect similar to that observed in the spatial domain" (p. 1119).

Three aspects of the study could have induced IOR. First, Fuentes et al. (1999), who used Spanish speakers, presented the target word in the left or right periphery. This spatial variation may have been needed to obtain semantic IOR, and semantic IOR may not appear without it. Second, Fuentes et al. used only two prime-target pairs (*dog-cat* and *hand-finger* and their corresponding variations, *dog-finger* and *hand-cat*, for the unrelated trials). Finally, these two pairs were presented repeatedly throughout the experiment, and it is quite possible that continued item repetition introduced item- or task-specific semantic IOR effects. We examine all three factors in the present study.

In our research, *semantic IOR* is defined as the process according to which attention is initially focused on a particular word or semantic concept (the prime) and subsequently shifted from this concept to a different semantic category. According to semantic IOR, a subsequent target word that is semantically related to the category of the original prime should be recognized more slowly than a target that is unrelated to the category of the prime, because the "return" to the meaning of the prime is inhibited.

EXPERIMENT 1

Experiment 1 was a close replication of Fuentes et al.'s (1999) Experiment 2, which, to the best of our knowledge, is the only published experiment so far that resulted in semantic IOR as defined above. The present experiment differed from the original experiment in two aspects. First, English word pairs were used (with native English speakers) rather than Spanish words (with native Spanish speakers). It was thus possible to verify that the observed effect of semantic IOR is language independent. More importantly, we examined the consequences of repetition. In Fuentes et al.'s experiment, the first third of the data (64 out of 192 trials, which were practice trials) was discarded and not included in the analyses. Is it possible that IOR developed only after a considerable amount of item repetition? Prolonged repetition of a stimulus set may alter recognition and be experienced as loss of item meaning: Responses to repeated items become slower (see, e.g., Amster, 1964), and the occurrence of IOR may depend on repetition.

To examine this possibility, we juxtaposed trials in the first block with trials in the last two blocks of the experiment. If IOR emerges with repetition, then it should be apparent in Blocks 2 and 3, as observed by Fuentes et al. (1999), but not in Block 1. In fact, semantic facilitation for related as opposed to unrelated words would be expected in the first block of the experiment, because the preestablished semantic relationship is very powerful in the absence of massive repetition.

Method

Participants—Twenty SUNY Binghamton undergraduates participated in this experiment in exchange for course credit.

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Materials and Procedure—The words used in this experiment were English equivalents of the Spanish words used by Fuentes et al. (1999). The words DOG and HAND served as primes, and the words BREAD and SEA or a string of four *X*s served as intervening stimuli. Prime words and intervening stimuli were shown in capital letters; target words (*cat* and *finger*) were shown in lowercase. The pseudowords *jat* or *fengir* served as nonword targets. Each target could be paired with either prime, so that DOG-*cat* and HAND-*finger* constituted the combination in the related condition and DOG-*finger* and HAND-*cat* were the combination in the unrelated condition. Since target nonwords were created from words by changing a letter or switching two letters from the corresponding target word, both words and nonwords were analyzed.

The sequence of events was as follows (see also Fuentes et al., 1999, Experiment 2): A fixation cross appeared in the center of the screen for 500 msec; after the cue, three boxes appeared on the screen, each of them subtending 5.4° × 1.3° of visual angle. The inner sides of the two peripheral boxes were located ±4.9° of visual angle away from fixation. All three boxes remained on the screen throughout the remainder of the trial. After a delay of 500 msec, the prime word appeared in the central box for 300 msec, followed by a 200-msec interstimulus interval (ISI) and the subsequent intervening stimulus that appeared for another 300 msec. After a second ISI of 150 msec, the target word appeared on the screen and remained visible until the participant pressed a response button.

Words were presented in black font on a white background. All trials were shown in random order. The prime and intervening stimuli were presented in the central box, whereas the target was presented in either the left- or the right-side box. The participants were instructed to determine whether the last stimulus in a row was a word or a nonword. They were also asked to pay attention to the full sequence of events. The participants responded to word targets with their dominant hand. Three blocks of 64 trials each were run, and the first block was used for practice.

The experiment was programmed in SuperLab Pro software. Word/nonword responses were made using a Microsoft serial mouse that was interfaced with a Dell personal computer. Mean RTs were submitted to a 2 × 2 × 2 repeated measures ANOVA, with relatedness (related or unrelated), intervening stimulus type (word or string of *X*s), and target location (left or right) as within-subjects factors.

Results

RTs below 250 msec and above 1,500 msec (1.6%), as well as incorrect responses (2.2%), were excluded from the RT analyses. Unless stated otherwise, data from the first block (the practice block) were also excluded from the initial analyses. Separate ANOVAs were conducted for words and nonwords.

Target location (left or right) did not exert a reliable influence, and it did not enter into any interaction, replicating the findings of Fuentes et al. (1999). Hence, the data from this factor were collapsed, and the ANOVA was repeated in a 2 × 2 design with relatedness and intervening stimulus type as within-subjects factors. Means, standard deviations, and error rates for word and nonword classifications are shown in Table 1.

For target words, there was no main effect of either semantic relatedness or intervening stimulus type (both *F*s < 1). However, the interaction of prime-target relatedness and intervening stimulus type was reliable [$F(1,19) = 4.65$, $p < .05$]. The analysis of the simple effects showed that RTs were longer with related than with unrelated target words when the intervening stimulus was a word, an effect that was marginally reliable [$F(1,19) = 4.04$, $p = .058$]. When the intervening stimulus was a string of *X*s, there was no difference ($F < .5$). There were no effects in the error data (all *F*s < 1.7).

For nonwords, there was only a main effect of target location; targets that appeared at the right side of the screen were responded to more quickly than were targets appearing at the left side ($F(1,19) = 10.69$, $p < .01$), indicating perhaps a response bias toward the right. No other effects or interactions reached significance. The error rates did not reveal any significant effects (all *F*s < 3).

Comparison of early and late trials—In order to examine whether or not the interaction of relatedness and intervening stimulus type was due to massive repetition, the data of the first third of the trials were contrasted with the data from the trials of the second and final thirds. Once again, all RTs smaller than 250 msec and larger than 1,500 msec were excluded. Also, the first five trials of each subject were excluded, to eliminate initial start-up effects. A 2 (sequence: early vs. late) × 2 (relatedness: related vs. unrelated) × 2 (intervening stimulus type: word vs. *X*s) ANOVA was applied to the data.

The data of the first block are shown in Table 2.

The results show a main effect of sequence, with faster RTs for the second and third sets of trials [$F(1,19) = 20.2$, $p < .001$]. Critically, there was no longer an interaction between relatedness and intervening stimulus type ($F < .1$). Instead, there was a robust triple interaction [$F(1,19) = 5.80$, $p < .05$], indicating that semantic IOR was observed for Blocks 2 and 3 but not for Block 1. In fact, related words in the early trials were processed faster than were unrelated ones, regardless of whether the intervening stimulus was a word or a string of *X*s, although the latter effect did not approach statistical significance [$F(1,19) = 1.17$, $p = .29$]. No other effects or interactions were reliable (all *F*s < 1.6).

Discussion

Experiment 1 replicates Fuentes et al. (1999), showing an interaction between intervening stimulus type and semantic relatedness, thereby providing evidence for IOR in the semantic domain. The fact that the same effect emerges with English and Spanish stimuli indicates that it is not language specific.

However, the present experiment also shows that semantic IOR emerges only after massive repetition, because the effect was not present in the first block of trials.

Experiment 2 extends Experiment 1 in that it examines whether semantic IOR with repeated items can also result when the spatial location of the target is no longer uncertain, as it was in Experiment 1.

EXPERIMENT 2

Experiment 2 was identical to Experiment 1, with one key difference. The spatial uncertainty of the target was eliminated, by presenting all of the words at the same location. If semantic IOR is independent of spatial factors, then the effects of Experiment 1 should be replicated.

Method

Participants—Twenty Binghamton University undergraduates participated in the experiment. None of them had participated in Experiment 1.

Materials and Procedure—The material and procedure were the same as in Experiment 1, with the exception that all words, including the target, appeared at the same location at the center of the screen. Mean RTs were submitted to a 2 × 2 repeated measures ANOVA, with relatedness (related or unrelated) and intervening stimulus type (word or string of *X*s) as within-subjects factors.

Results

RTs below 250 msec and above 1,500 msec (0.9%) and incorrect responses (1.8%) were excluded from the RT analyses. Separate analyses were applied to words and nonwords. Means, standard deviations, and error rates for items from Blocks 2 and 3 are depicted in Table 3.

For target words, there was no main effect of semantic relatedness or of intervening stimulus type (both *F*s < 2), but the interaction of prime-target relatedness and intervening stimulus type was once again reliable [$F(1,19) = 5.21$, $p < .05$]. The analysis of simple main effects showed that RTs were longer with related than with unrelated targets when the intervening stimulus was a word [$F(1,19) = 7.85$, $p < .05$], thus replicating the IOR effect. There was no prime-target relatedness effect when the intervening stimulus was a string of *X*s ($F = .9$).

To test for repetition effects, we contrasted trials from the first block with those in the last two blocks. Once again, the IOR effect was absent in the first block ($F = .03$). It was highly reliable for Blocks 2 and 3, showing that semantic IOR requires massive item repetition. The data from the first block are presented in Table 4.

The accuracy data did not show any reliable effect for Blocks 2 and 3 (all *F*s < 1.1). For the first block, there was an uninformative interaction between relatedness and intervening stimulus type, with fewer, not more, errors for related words when the intervening stimulus was a word [$F(1,19) = 5.35$, $p < .05$], indicating the absence of a semantic IOR effect. No other effects reached significance (all *F*s < .2).

Nonwords did not show any reliable effect in the RT or the accuracy analyses (all *F*s < 1.4).

Comparison of Experiments 1 and 2—Did spatial uncertainty of the target have any effect on target classification? To examine this question, we ran a 2 × 2 × 2 ANOVA, with relatedness and intervening stimulus type as within-subjects factors, and experiment (spatial properties of the prime) as a between-subjects factor.

The results revealed a main effect of experiment, indicating that targets in the central location (Experiment 2) were responded to more quickly than were targets appearing at a peripheral location [$F(1,38) = 11.58$, $p < .01$]. The interaction of relatedness and intervening stimulus type was also significant [$F(1,38) = 9.64$, $p < .01$], indicating that the semantic IOR effect was present in the pooled data from Experiments 1 and 2. No further main effect or interaction reached significance (all *F*s < 1.1).

Experiments 1 and 2 differed not only in that there was spatial variability in Experiment 1. Spatial variability was also correlated with spatial predictability. Even though both factors were eliminated simultaneously in Experiment 2, the absence of a triple interaction indicated that the IOR effect was equivalent for central as opposed to peripheral target presentation ($F < .5$). Hence, neither spatial variability nor uncertainty about the target location is likely to have played a significant role.

Discussion

Experiment 2 revealed semantic IOR in the absence of any spatial uncertainty. Therefore, Experiment 2 offers the first evidence of a high-level, location-independent effect of semantic IOR. Earlier studies have shown IOR in the absence of spatial uncertainty in the auditory domain, for duration, intensity, or timbre (Mondor & Lacey, 2001), and in the visual domain for the length of a line (Francis & Milliken, 2003). These studies, however, clearly required a perceptual judgment and did not involve symbol-analyzing cognitive processes.

Critically, however, semantic IOR was present only in Blocks 2 and 3. Why was this the case? On the one hand, it could be a consequence of general practice with the experimental task. Semantic IOR should then occur after a number of trials have been completed. Alternatively, extensive repetition of items may be required to cause semantic IOR. We tested these alternatives in Experiment 3 by using nonrepeated items on all trials.

EXPERIMENT 3

A total of 64 different categories were used, to avoid repetition. If item repetition is the cause of semantic IOR as observed in Experiments 1 and 2, no inhibition is expected in this experiment, because no trials are repeated. On the contrary, related items should be responded to more quickly than are unrelated items because of semantic priming. This priming effect is even predicted for trials with intervening unrelated words, because semantic facilitation is robust in the presence of intervening items. Scarborough, Cortese, and Scarborough (1977), for instance, showed that repetition priming can occur with as many as 32 intervening items. Joordens and Besner (1992) observed a reliable, though small, semantic priming effect that spanned across an intervening unrelated item, and Becker, Moscovitch, Behrmann, and Joordens (1997) showed that semantic priming can last for up to as many as 8 intervening items.

If semantic IOR is merely a practice effect, however, then it should emerge later in the experiment.

Method

Participants—Sixteen Binghamton University students participated in this experiment. None of them had participated in Experiments 1 or 2.

Materials and Procedure—A total of 64 stimulus pairs were selected. Each prime (e.g., KING) was accompanied by two target alternatives: a related (e.g., *crown*) or an unrelated (e.g., *birth*) target. Prime and target words were between three and five letters long (one six-letter target word was included). All prime and target words were monosyllabic, and the related and unrelated targets were closely matched in frequency (related: 71.6 per million; unrelated: 72.5 per million); each related target had the same number of letters as its unrelated companion (average: 4.15 letters for both related and unrelated targets). For each pair, an intervening stimulus was selected (three to five letters long) that was unrelated to both the prime and the target word. An intervening string of asterisks, identical in length to the word, served as the neutral stimulus.

A given prime appeared with either a related or an unrelated target in different versions of the experiment. Relatedness as a factor was crossed with type of intervening stimulus (word or asterisk), yielding a total of four lists for the experiment. There were 16 stimuli in each of the four conditions; 8 of them were words. Pronounceable nonwords were created by replacing one letter of each of the remaining 8 targets with a different letter, so that both the word and non-word conditions contained related and unrelated pairs. Moreover, 16 identical pairs were added for both the word and the nonword condition, half of which had an unrelated word as the intervening stimulus, whereas the other half had an asterisk in between the prime and the target. This yielded a total of 96 stimulus pairs for the experiment. In the word-identical condition, the targets were the same as the primes. In the nonword-identical condition, they were not quite the same, because nonword targets had one of the letters of the prime replaced. Once again, all primes and intervening words were presented in uppercase font, whereas all targets were presented in lowercase font, to reduce the amount of perceptual overlap.

The procedure was identical to the procedure used in Experiment 2, with two minor differences: Because all words (including the target) were presented in the center of the screen, no peripheral boxes were shown; the central boxes were also removed in this experiment. Moreover, unlike in Experiments 1 and 2, in which each of the three blocks contained the exact same type and number of trials, Experiment 3 had no repetition whatsoever.

The experiment was preceded by a practice block of 10 items. Mean RTs were submitted to a 3 × 2 repeated measures ANOVA, with relatedness (identical, related, or unrelated) and intervening stimulus type (word or asterisk) as within-subjects factors.

Results

Outliers (5.2%) as well as incorrect responses (5.3%) were not included in the RT analyses. Separate analyses were applied to words and nonwords. Means, standard deviations, and error rates are depicted in Table 5.

Words revealed a robust main effect of semantic relatedness, with identical words yielding faster RTs (675 msec) than related (684 msec) and unrelated (721 msec) words [$F(2,30) = 4.51$, $p < .05$]. There was also a main effect of intervening stimulus type, with slower responses when the intervening stimulus was a string of asterisks rather than a word [718 msec vs. 669 msec; $F(1,15) = 9.91$, $p < .01$]. There was no interaction between the two factors [$F(2,30) = .17$, $p = .84$].

Post hoc tests indicated that related words yielded faster rather than slower response latencies when the intervening stimulus was a word, although the effect was only marginally significant [$F(1,15) = 3.37$, $p = .086$].

Error analyses revealed an effect of semantic relatedness, with more errors in the unrelated condition (7%) than in both the related (2.65%) and the identical (2.3%) conditions [$F(2,30) = 5.05$, $p < .05$]. No other effects were significant (both *F*s < .5).

Nonword RTs revealed a main effect of intervening stimulus type, with longer response latencies when the intervening stimulus was an asterisk rather than a word—834 msec and 803 msec, respectively [$F(1,15) = 4.62$, $p < .05$], mimicking the word analyses. There was no effect of semantic relatedness and no interaction (both *F*s < 1.1). Error analyses for nonwords revealed an uninformative interaction of semantic relatedness and intervening stimulus type [$F(2,30) = 3.42$, $p = .046$]. No other effects reached significance (all *F*s < 1).

Using a method similar to that used in the previous experiments, in which the effect of sequence was examined, the data from Experiment 3 were subjected to an additional analysis of block sequence. To mimic the analyses of Experiments 1 and 2, the data set of each participant was divided into three segments: Trials from the first part (or block) were juxtaposed with those from the following two blocks. A 3 (relatedness: unrelated, related, or identical) × 2 (intervening stimulus type: word vs. asterisk) × 2 (sequence: first part vs. subsequent parts) ANOVA was run. Once again, the results show an effect of semantic relatedness[2] [$F(2,20) = 3.78$, $p < .05$] and of intervening stimulus type [$F(1,10) = 10.26$, $p < .001$]. No other effects were significant; specifically, there was no effect of block sequence, and block sequence did not enter into any significant interaction[3] (all *F*s < 2.7).

[2]Due to the reduced number of data (Block 1 consisted of only one third of the experiment) and due to the randomized presentation (not all conditions may necessarily have been covered in the initial third), many cells remained empty, which is the reason for the reduced number of degrees of freedom.

Discussion

There was no evidence of semantic IOR in Experiment 3. To the contrary, robust benefits of semantic relatedness emerged throughout the experiment. These findings are in striking contrast to the results of Experiments 1 and 2, in which inhibitory effects became apparent after massive repetition. Experiment 3 differed from Experiments 1 and 2 in that there was less general practice and in that repetition trials with identical primes and targets were added. Critically, in Experiment 3, all targets were presented in a central location. Could the absence of spatial variability have obscured a semantic IOR component in Experiment 3? Because earlier studies have examined high-level (i.e., cognitive) IOR only in conjunction with a spatial variation (Chasteen & Pratt, 1999; Fuentes et al., 1999), Experiment 4 reemployed the lateralized presentation of target words to determine whether semantic IOR can reemerge in the absence of item repetition.

EXPERIMENT 4

Experiment 4 reintroduced spatial variation. It explored the final cell in the 2 × 2 matrix of spatial (central vs. peripheral presentation) and semantic (repetitive vs. novel stimulus material) variability. If the elimination of spatial variability is irrelevant in cases in which stimuli are repeated, but does exert an effect on IOR under conditions of broader semantic variability, then IOR may be observed in the present experiment.

Method

Participants—Twenty-four Binghamton University students participated in this study for course credit. None of them had participated in any of the previous experiments.

Materials and Procedure—The materials and procedure used were the same as those used in Experiment 3 except for the following modifications: After the initial fixation cue, three boxes appeared on the screen, identical to those used in Experiments 1 and 2. The boxes subtended 5.4° × 1.3° of visual angle, and the inner sides of the two peripheral boxes were located ±4.9° of visual angle away from fixation. All three boxes remained on the screen throughout the remainder of the trial. The target was presented randomly inside the left or right box. Stimulus durations and ISIs were identical to those used in the previous experiments. The participants were asked to decide whether a target was a word or a nonword, and were told to press the corresponding mouse button as quickly as possible. Once again, the experiment was preceded by a short practice block of 10 items. Mean RTs were submitted to a 3 × 2 × 2 repeated measures ANOVA, with relatedness (identical, related, or unrelated), intervening stimulus type (word or asterisk), and target location (left or right) as within-subjects factors.

Results

Outliers (2.9%) as well as incorrect responses (6.4%) were not included in the RT analyses. Separate analyses were conducted for words and nonwords. The data are shown in Table 6.

Once again, there was a robust effect of semantic relatedness, with identical words yielding faster response latencies (708 msec) than both related (737 msec) and unrelated words (784 msec) [$F(2,46) = 38.72$, $p < .001$]. Moreover, targets appearing on the right side were responded to more quickly than were those appearing on the left, 721 msec and 766 msec, respectively [$F(1,23) = 18.46$, $p < .001$]. There was no longer a main effect of intervening stimulus type

[3]There was a marginally significant triple interaction [$F(2,20) = 2.61$, $p = .1$]. However, this effect was apparently caused by identical trials and not by an interaction between intervening stimulus type and related as opposed to unrelated words: There was a strong difference in RTs to identical targets, with faster responses after an intervening word than after an intervening asterisk for early trials only, not for later ones [$F(1,14) = 12.83$, $p < .01$]. This difference (134 msec) presumably accounts for the effect.

($F < 2$), but intervening stimulus type entered into a reliable interaction with target location, in that targets were responded to more slowly after an intervening asterisk than after a word when they appeared at the right- but not at the left-side location [$F(1,23) = 4.77$, $p < .05$].

Once again, there was no interaction between relatedness and intervening stimulus type ($F < 2.6$), but the triple interaction between all factors reached significance [$F(2,46) = 5.8$, $p < .01$]. However, there was no sign of the predicted pattern (longer response latencies for related as opposed to unrelated words after an intervening asterisk), in that related words were responded to more quickly than were unrelated ones in all the blocks.

Comparisons of the first block with Blocks 2 and 3 were complicated by the fact that many cells for the initial part were missing.[4] However, a 3 × 2 × 2 ANOVA (with relatedness, intervening item type, and target side as repeated measures factors) for trials in the later part of the experiment revealed only a main effect of relatedness [$F(2,34) = 14.72$, $p < .001$], with identical and related targets responded to more quickly than were unrelated ones. There was also a main effect of target side [$F(1,17) = 20.16$, $p < .001$] and an uninformative interaction between intervening stimulus type and target side that approached significance [$F(1,17) = 3.098$, $p = .096$]. No other effects or interactions reached significance (all Fs < 1.3).

The analysis of error rates produced a robust effect of semantic relatedness, with identical words yielding lower error rates (1.3%) than did both related (2.0%) and unrelated (8.0%) words [$F(2,46) = 14.65$, $p < .001$]. No other effects were significant.

The analysis of target nonwords did not produce any reliable effects for either the RT (all Fs < 2.2) or error data (all Fs < 2.4).

Comparison of Experiments 3 and 4—Because the same items were used in Experiments 3 and 4, a between-experiments analysis was conducted to test for the hypothesized semantic IOR effect with a larger participant sample; however, because all of the words were presented in the center of the screen in Experiment 3, location of the target was not included as a factor. The results reveal the expected main effect of relatedness [$F(2,76) = 26.7$, $p < .001$]. Moreover, there was a significant effect of intervening stimulus type: Words presented after an asterisk were processed more slowly than were those presented after intervening words. However, this effect was further qualified by a reliable interaction between experiment and intervening stimulus type [$F(1,38) = 5.022$, $p < .05$]. More specifically, the effect of intervening item type was strong in Experiment 4, but rather weak in Experiment 3. No other effects or interactions reached significance (all Fs < 1.5).

Discussion

The robust benefit of semantic relatedness throughout the experiment confirms the results of Experiment 3, showing that processing of nonrepeated prime-target words is not subject to semantic IOR and that a facilitatory effect of relatedness occurs regardless of the spatial relationship between the prime and the target.

Interestingly, in contrast to the results of Experiment 1, the analyses of the present experiment also revealed an effect of target location, with right-side targets being responded to more quickly than left-side targets. This is most likely due to processing differences for stimuli presented in the right as opposed to the left hemifield, in that words presented on the right side of the screen may enjoy a processing advantage. They may attract attention because English

[4]Because no repetition occurred in this experiment, there was no reason to present trials in a blocked manner. Therefore, all trials were randomized. The initial part therefore included fewer observations, and missing cells were more common than in the second and the final thirds.

words are read from left to right, or they may benefit from a more direct access of language-based left-hemispheric processing resources. Also, overall RTs in this experiment were much slower than were RTs in Experiment 3, presumably because the eyes had to be moved to the peripheral items before a discriminating response could be made.

EXPERIMENT 5

The previous experiments have shown that item repetition is necessary for semantic IOR to occur. When nonrepeated items are used, facilitation for semantically related items occurs. In addition to introducing item repetition, Experiments 1 and 2 differ from Experiments 3 and 4 in yet another dimension: A homogeneous as opposed to a heterogeneous item pool was used. In Experiments 1 and 2, only 4 item pairs (2 word and 2 nonword pairs) were used, whereas 96 different pairs were included in Experiments 3 and 4. As a result, item homogeneity may also have been necessary for the semantic IOR in Experiments 1 and 2. We examined this possibility in Experiment 5. To do so, we interspersed the repeated items of Experiments 1 and 2 with the nonrepeated items of Experiments 3 and 4. If item repetition is exclusively responsible for IOR, then item homogeneity should not have an impact. That is, mixed blocks should yield semantic IOR for repeated related items and facilitation for nonrepeated related items. On the other hand, it is possible that semantic IOR depends on item homogeneity. This is not an unrealistic assumption, given that previous IOR experiments used both repeated items (or repeated locations) as well as a small pool of items (usually two—e.g., squares and diamonds, in a discrimination task) or locations (once again, usually two—the left or right periphery). The results of Experiments 1 and 2 could thus have differed from those of Experiments 3 and 4 because a *small number* of items was used.

Method

Participants—Twenty Binghamton University undergraduate students participated in this experiment. None of them had participated in any of the previous experiments.

Materials and Procedure—The 4 pairs of repeated stimuli from Experiments 1 and 2 (DOG-*cat*; HAND-*finger*, and their respective nonword counterparts) and the 64 pairs[5] of nonrepeated stimuli from Experiments 3 and 4 were used. In a total of three blocks, the number of presentations for repeated items was identical to the number used in Experiments 1 and 2. The 64 nonrepeated items from Experiments 3 and 4 were split equally[6] across the three blocks. The prime and intervening stimuli (a word or a string of *X*s) were presented in the central box, whereas the target was presented in either the left or the right box. All other aspects of the material and procedure were identical to those in the previous experiments.

Results

Outliers (0.9%) as well as incorrect responses (3.95%) were not included in the RT analyses. Separate analyses were conducted for words and nonwords. The data are shown in Table 7.

Repeated items were responded to more quickly than were nonrepeated items [$F(1,19) = 97.75$, $p < .001$]. Averaged across Blocks 2 and 3, there was also a main effect of relatedness, with related items being responded to more quickly than were unrelated ones [$F(1,19) = 26.37$, $p < .01$]. Moreover, there was an interaction between repetition condition and prime-target relatedness [$F(1,19) = 11.76$, $p < .01$], indicating that there was a strong semantic relatedness effect for novel items, whereas such an effect was absent for the repeated items. Critically, in the condition in which intervening words rather than a string of *X*s separated the prime and

[5]Identical items were not used in this experiment.

[6]The item distribution across the blocks (21-21-22) was varied across the different lists of the experiments.

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target stimuli, there was virtually no effect for repeated items [$F(1,19) = .88$, $p = .36$], whereas there was robust semantic priming for novel items [$F(1,19) = 18.11$, $p < .001$]. The triple interaction failed to reach significance, however [$F(1,19) = 1.96$, $p = .17$]. No other effects or interactions were significant (all *F*s < 1.2). For the nonword analyses, there was a robust effect of repetition, with repeated nonwords being responded to more quickly than were nonrepeated ones [$F(1,19) = 89.1$, $p < .001$]. No other effects or interactions reached significance (all *F*s < 1.5).

The error analyses for words showed that there was a main effect of semantic relatedness, with related words being processed more accurately than unrelated words [$F(1,19) = 14.47$, $p < .01$]. No other effects approached significance (all *F*s < 1.6). For nonword targets, there was an effect of semantic relatedness, with nonword targets generated from related words being responded to more accurately than were unrelated nonword targets, an effect that approached significance [$F(1,19) = 3.77$, $p = .07$]. The analysis also revealed an interaction of prime-target relatedness with intervening stimulus type [$F(1,19) = 6.25$, $p < .05$]. No other effects or interactions reached significance (all *F*s < 1).

Discussion

Experiment 5 was similar to Experiments 1 and 2 in that items were repeated multiple times in a total of three blocks; it was similar to Experiments 3 and 4 in that nonrepeated items were used. However, it differed from the previous experiments in that novel and repeated items were interspersed. Under these conditions, semantic facilitation was obtained for nonrepeated items. For repeated items, on the other hand, the inhibitory effect was absent. The results indicate that both a homogeneous item pool as well as item repetition are necessary for semantic IOR to occur. These findings may have general implications for the study of inhibitory effects of attention, because most studies on different IOR types entertain both item repetition as well as a relatively small item pool as critical design characteristics.

GENERAL DISCUSSION

The present study explored the generality of semantic IOR, previously reported by Fuentes et al. (1999). Specifically, we examined whether semantic IOR depends on variability of the target location, on repetition, or on the homogeneity of the item pool.

Experiment 1 and Experiment 2 provide the first evidence of a high-level IOR effect in the absence of spatial variation; this finding confirms and extends Fuentes et al.'s (1999) previously reported semantic IOR effect. Critically, however, semantic IOR occurred only after massive repetition, and facilitation occurred with nonrepeated items in Experiments 3 and 4. Moreover, Experiment 5 showed that semantic IOR is absent when the pool of items is heterogeneous.

Semantic IOR denotes the phenomenon that targets are recognized more slowly when they are semantically related to a prime and when an intervening unrelated word has shifted attention to a different semantic category prior to target processing. No inhibition occurs when the intervening item is a neutral stimulus, because attention is not removed from the primed category, and inhibition of *return* cannot occur. Why does semantic IOR occur with a repeated set of items only?

We propose that semantic IOR may affect responses to both repeated and nonrepeated items, but that it is initially overshadowed by robust facilitatory effects of semantic relatedness. Repeated exposure of a relatively small number of related and unrelated word pairs can result in semantic IOR for semantically related words, because the shifting away from a primed category may make it increasingly more difficult to shift processes back to this particular category. That is, the shifting away from a primed semantic category may go along with a relatively small amount of inhibition for that category. Initially, the effect of this inhibition will be negligible, so that effects of semantic relatedness predominate. The episode-specific inhibition of a previously activated semantic concept may build up with repetition, however, especially under conditions of massive item repetition, as occurred in the homogeneous item contexts of Experiments 1 and 2. Eventually, the episode-specific buildup of inhibition for a previously activated semantic concept will exceed the benefit of semantic relatedness, thus yielding semantic IOR. The buildup of inhibition may be much less effective when repeated items occur in the context of novel words, which increases the lag between the repetition of related items; this occurred in Experiment 5. Consequently, the net effect of semantic IOR will be smaller, so that it will roughly match the benefit of semantic relatedness in the heterogeneous item context of Experiment 5. Finally, semantic relatedness effects should dominate the inhibition of a previously activated semantic concept in the absence of any repetition, as occurred in Experiments 3 and 4.

This means that semantic IOR will be an exception rather than the rule. In fact, semantic IOR may be limited to relatively rare circumstances. Semantically related concepts are often encountered throughout a text. For instance, when talking about a nurse, there is some likelihood that “doctor,” “hospital,” and so on will also be mentioned. Therefore, the presence of a general semantic IOR effect for nonrepeated or rarely repeated items in a heterogeneous word context would disrupt rather than benefit language processing. Similarly, in common conversations, speakers often return to a semantic category; thus, it would be ineffective if a previously attended category were to be inhibited immediately.

More evidence for this view comes from semantic priming studies. Even though most research investigates semantic priming at relatively short intervals only, several studies have shown that semantic priming can be maintained for a long time, even if intervening stimuli attract attention to different categories (Becker et al., 1997; Joordens & Becker, 1997; Scarborough et al., 1977). As a result, facilitatory semantic priming may predominate when a sufficiently heterogeneous pool of nonrepeated items is used.

The key result of our study—that repeated exposure of words as well as item homogeneity are necessary for semantic IOR to occur—may be due to a general principle according to which IOR effects require extensive repetition and little item variability. As a result, the present findings may have more far-reaching implications, because virtually all studies of perceptual IOR use extensive repetition and homogeneous item pools. In common spatial-detection tasks, for instance, a simple target is used that appears in one of a small set of locations. Similarly, IOR studies with identification judgments use few potential targets, for example, a square or a diamond (see, e.g., Pratt, 1995); there is a considerable amount of repetitiveness, and item variability is exhausted after only a few trials. Future experiments will have to determine whether repetition is necessary for IOR to occur.

Semantic IOR effects appear similar to negative priming effects, and the question can be asked whether they have a common underlying mechanism. In a standard negative priming task, participants see a pair of stimuli, one of which is to be attended (and responded) to, while the other is to be ignored (for a review, see Fox, 1995). When the target of the following trial is the to-be-ignored stimulus from the previous one, responses are delayed, as compared with when the target is an unrelated item that was not previously shown. Critically, negative priming also develops only after considerable item repetition. In a pair of experiments, Grison and Strayer (2001), for instance, presented targets either twice or an average of 78 times in the experiment. Negative priming occurred only for the repeated items. These findings are similar to those obtained in Experiments 1 and 2 of the present study.

There are several differences, however, that are important to consider when looking for common and different mechanisms that may underlie negative priming and semantic IOR. In Grison and Strayer's (2001) experiment, repeated and nonrepeated trials were mixed. Inhibition occurred for repeated items, but there was no facilitatory effect for nonrepeated items. In Experiment 5, by contrast, novel related items yielded semantic facilitation, and repeated semantic items yielded neither facilitation nor inhibition. In the negative priming paradigm, targets must be processed and distractors must be inhibited. Therefore, the critical aspect is to block distracting information from interfering with target processing. In semantic IOR, on the other hand, a relatively small inhibitory effect may be designed to merely bias attention from returning to a previously activated concept when another concept was activated in the meantime. The central purpose of this may be to orient attention toward novelty (Klein, 2000). These differences—an emphasis on inhibiting simultaneous irrelevant information versus an emphasis on merely biasing attention to novelty—may account for the differences between the results of the present study and those observed by Grison and Strayer. These differences also suggest that semantic IOR and negative priming may be supported by distinct mechanisms. Future experiments will need to determine whether or not this is the case.

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Table 1

Mean Reaction Times (in Milliseconds), Standard Deviations, and Error Rates (PEs) as a Function of Prime-Target Relatedness and Intervening Stimulus Type for Both Target Words and Nonwords in Blocks 2 and 3 of Experiment 1

	Intervening Stimulus					
	Word			*XXXX*		
	M	*SD*	PE	*M*	*SD*	PE
Words						
Related	713	76	2.5	704	99	3.2
Unrelated	692	78	3.1	709	107	1.2
Nonwords						
Related	724	92	2.0	729	84	1.6
Unrelated	742	82	2.2	719	67	2.4

Table 2

Mean Reaction Times (in Milliseconds), Standard Deviations, and Error Rates (PEs) as a Function of Prime-Target Relatedness and Intervening Stimulus Type for Trials Occurring Early in Experiment 1 (in the First Block, Comprising 64 Trials)

	Intervening Stimulus					
	Word			*XXXX*		
	M	*SD*	PE	*M*	*SD*	PE
Words						
Related	751	104	0.6	776	73	2.0
Unrelated	782	143	1.9	788	150	3.8
Nonwords						
Related	826	103	3.1	809	128	2.5
Unrelated	803	122	4.2	815	118	1.4

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Table 3

Mean Reaction Times (in Milliseconds), Standard Deviations, and Error Rates (PEs) as a Function of Prime-Target Relatedness and Intervening Stimulus Type for Both Target Words and Nonwords in Blocks 2 and 3 of Experiment 2

	Intervening Stimulus					
	Word			***XXXX***		
	M	***SD***	**PE**	***M***	***SD***	**PE**
Words						
Related	624	99	2.1	604	93	1.5
Unrelated	596	74	2.5	614	111	2.8
Nonwords						
Related	639	111	1.2	643	131	1.2
Unrelated	629	116	1.8	643	107	1.2

Table 4

Mean Reaction Times (in Milliseconds), Standard Deviations, and Error Rates (PEs) as a Function of Prime-Target Relatedness and Intervening Stimulus Type for Trials Occurring Early in Experiment 2 (in the First Block, Comprising 64 Trials)

	Intervening Stimulus					
	Word			*XXXX*		
	M	*SD*	PE	*M*	*SD*	PE
Words						
Related	629	106	0.7	629	92	2.7
Unrelated	631	95	3.6	635	114	0.7
Nonwords						
Related	679	137	3.0	680	122	3.2
Unrelated	667	138	1.3	665	125	2.7

Table 5

Mean Reaction Times (in Milliseconds), Standard Deviations, and Error Rates (PEs) as a Function of Prime-Target Relatedness and Intervening Stimulus Type for Both Target Words and Nonwords in Experiment 3

	Intervening Stimulus					
	Word			Asterisks		
	M	***SD***	**PE**	***M***	***SD***	**PE**
Words						
Identical	647	141	2.3	703	181	2.3
Related	657	167	2.3	711	233	3.0
Unrelated	703	153	7.0	740	182	7.0
Nonwords						
Identical	786	158	13.0	846	193	3.0
Related	800	211	5.0	828	196	8.0
Unrelated	824	190	7.0	829	198	7.0

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Table 6

Mean Reaction Times (in Milliseconds), Standard Deviations, and Error Rates (PEs) as a Function of Prime-Target Relatedness and Intervening Stimulus Type for Both Target Words and Nonwords in Experiment 4

	Intervening Stimulus					
	Word			Asterisks		
	M	***SD***	**PE**	***M***	***SD***	**PE**
Words						
Identical	698	104	1.5	715	111	1.0
Related	741	107	2.0	731	95	2.0
Unrelated	768	122	9.3	799	112	6.7
Nonwords						
Identical	864	100	5.4	883	125	4.1
Related	888	174	8.1	884	136	7.9
Unrelated	869	128	12.7	867	144	6.3

Table 7

Mean Reaction Times (in Milliseconds), Standard Deviations, and Error Rates (PEs) as a Function of Prime-Target Relatedness, Intervening Stimulus Type, and Item Repetition for Both Target Words and Nonwords in Experiment 5

	Intervening Stimulus					
	Word			***XXXX***		
	M	***SD***	**PE**	***M***	***SD***	**PE**
Novel Items						
Words						
Related	717	100	0.9	754	117	2.9
Unrelated	794	115	5.7	791	112	7.6
Nonwords						
Related	886	130	4.7	912	126	9.5
Unrelated	872	172	14.2	874	162	5.7
Repeated Items						
Words						
Related	661	83	1.25	658	89	1.3
Unrelated	669	84	2.5	670	102	3.4
Nonwords						
Related	708	68	2.1	717	75	2.5
Unrelated	712	73	5.3	711	77	3.4