Research Article

THE EFFECT OF INHIBITION OF RETURN ON LEXICAL ACCESS

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Abstract—*Inhibition of return refers to a bias against returning attention to a location or object that has been recently attended. Recent research has shown that inhibition of return can be found not only in simple detection tasks, but also in tasks requiring relatively simple discrimination judgments. The present experiments examined whether inhibition of return occurs in tasks that require complex discriminations such as lexical decision and categorization tasks. Not only was inhibition of return found in both experiments, but a greater amount of inhibition was found for low-frequency words than for high-frequency words. These findings suggest that inhibition of return not only inhibits returning attention to previously attended locations, but can also affect the processing that is required for lexical access.*

Following the cuing of attention to a peripheral location, detection responses to targets presented at that location are briefly facilitated. Following this brief period of facilitation is a longer period in which detection responses are inhibited for targets at the cued location. This effect has been termed *inhibition of return*, referring to the notion that the inhibition may reflect a bias against returning attention to previously attended locations (Posner & Cohen, 1984). It has been suggested that inhibition of return helps to make visual searches more efficient by directing attention to novel locations and away from locations that have already been attended (e.g., Tipper, Weaver, Jerreat, & Burak, 1994).

If inhibition of return does reflect a mechanism that improves the efficiency of searches, then the inhibition would be expected to be found in tasks that require some type of discrimination judgment, not just in simple detection tasks. This is because the majority of searches that people perform involve determining the location or the identity of a specific item among distracting items, not detecting the sudden appearance of a single item in an otherwise empty visual field. Recent evidence suggests that inhibition of return does indeed occur in situations that require the determination of the location or the identity of a target stimulus (Lupiáñez, Milán, Tornay, Madrid, & Tudela, 1997; Pratt, 1995; Pratt & Abrams, in press; Pratt, Kingstone, & Khoe, 1997; but see also Terry, Valdes, & Neill, 1994). For example, in a study investigating how inhibition of return affects discriminations between targets and nontargets (Pratt et al., 1997), two choice decision tasks were used: a location-based task in which participants made key-press responses to the location of a target (left or right) and an identity-based task in which participants made key-press responses to the identity of a target (*X* or +). Inhibition of return was found in both tasks: Subjects were slower to make target discriminations when the location of the target had been previously cued.

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Although there is good evidence that inhibition of return exists in some discrimination tasks, it remains unknown whether inhibition of return affects complex target discriminations. For the most part, the studies that have found inhibition of return in discrimination tasks have used stimuli that could be distinguished on the basis of their physical appearance. For example, participants have made discriminations between an *X* and a + (Pratt et al., 1997), between squares and diamonds (Pratt, 1995), between the letters *A* and *B* (Pratt & Abrams, in press), and between yellow and red asterisks (Lupiáñez et al., 1997). Examining how inhibition of return might affect discriminations between words and nonwords (e.g., *hornets* vs. *hirnits*) would not only demonstrate the generalizability of inhibition of return, but would also provide some insight into whether inhibition of return affects other higher order cognitive processes, such as those used in visual word recognition and reading.

EXPERIMENT 1

In this experiment, participants were asked to determine if a string of letters, presented at either a cued or an uncued location, formed a word or a nonword. Word frequency was also manipulated to examine if there would be differences in the amount of inhibition of return for words that required more (low-frequency words) or less (high-frequency words) processing. Overall, we expected to find two effects. First, we expected standard word-frequency effects: faster responses to high-frequency words than to low-frequency words and to nonwords, and faster responses to low-frequency words than to nonwords. Second, we anticipated finding evidence of inhibition of return: slower responses to previously cued locations than to uncued locations. However, it was unknown if inhibition of return would differentially affect word processing, which would be indicated by an interaction between word frequency and cuing.

Method

Participants

Ten undergraduate students from the University of Toronto each participated in a single experimental session. They participated to fulfill a course requirement.

Materials

The stimulus set consisted of 64 high-frequency and 64 low-frequency words, drawn from a list developed by Balota and Chumbley (1985). Word frequency was based on the Kučera and Francis (1967) norms; the low-frequency words had counts less than 7 per million (M = 1.57 occurrences per million, range: 1–4), and the high-frequency words had counts greater than 36 per million (M = 157.67 occurrences per million, range: 40–1,164). Word length ranged from three to seven letters, and high- and low-frequency words were matched for length.

Following Balota and Chumbley (1984), we developed 128 pronounceable nonwords by changing up to three letters within the words (e.g., *hornets* was changed to *hirnits*).

Apparatus and procedure

Participants were seated directly in front of a computer monitor, and their heads were placed in a chin- headrest located 40 cm from the monitor. A keyboard was placed directly in front of them so that they could easily press any of the keys.

Figure 1 shows the sequence of events for each trial. At the beginning of each trial, a display consisting of a central fixation dot and two peripheral boxes (one above and one below the fixation dot) was presented. The peripheral boxes were 2° high and 4° wide and were centered 2° above and below the fixation point. When the display appeared, participants were instructed to fixate on the fixation dot and remain fixated until a string of letters appeared in one of the boxes. A cue was presented at one of the boxes 1,500 ms after the appearance of the display. This cue consisted of one of the boxes being filled in; it appeared on the screen for 200 ms and then was removed. After a 200-ms delay, a cue was presented at the fixation point for 200 ms and was then removed. After a delay of 200 ms, the target, either a word or a nonword, was presented in one of the peripheral boxes.

Key-press responses were counterbalanced across participants. Half of the participants were instructed to press the "z" key if the target was a word and to press the "/" key if the target was a nonword, whereas the other half of the participants were instructed to do the opposite. The target remained on the display either until the participant responded or until 2,000 ms had elapsed since its onset. If the participant made an error in responding (pressed the wrong key) or the reaction time (RT) was less than 100 ms or more than 2,000 ms, a brief error tone was presented. The intertrial interval was 1,500 ms. Prior to the presentation of the test trials, participants completed a block of 30 practice trials.

Design

The single session consisted of one block of 256 trials. For each trial, the cue and target were equally likely to appear in either box. Thus, in half of the trials the target was presented at the cued location, and in the other half the target was presented at the uncued location. Each type of target (high- or low-frequency word or nonword) was also equally likely on each trial.

Results and Discussion

Each participant's data were checked for errors and outliers. Following the criteria used by Balota and Chumbley (1984), we defined an outlier as any RT that was either less than 200 ms or 3 standard deviations above the mean for that condition. All errors and outliers were excluded from the latency analyses.

Latencies

Figure 2 shows the mean RTs from the trials with correct responses. A 2 (trial type: cued vs. uncued) × 3 (word frequency: high-frequency word vs. low-frequency word vs. nonword) analysis of variance (ANOVA) was conducted on the mean RTs. There was a significant main effect for trial type, $F(1, 9) = 35.32$, $MSE = 2{,}637$, $p < .001$. Responses were slower in the cued ($M = 879$ ms) than in the uncued ($M = 800$ ms) condition, which is the typical inhibition-of-return effect. There was also a significant main effect for word frequency, $F(2, 18) = 51.48$, $MSE = 2{,}558$, $p < .0001$. Results were consistent with the common effects of word frequency: Responses to high-frequency words were the fastest ($M = 747$ ms), followed by responses to low-frequency words ($M = 876$ ms) and then responses to nonwords ($M = 896$ ms). Student's t tests revealed that the mean RTs for high- and low-frequency words were significantly different from one another ($p < .001$), and RTs for high-frequency words were significantly different from RTs for nonwords ($p < .001$). The mean RTs for low-frequency words and nonwords, however, were not significantly different ($p > .05$).

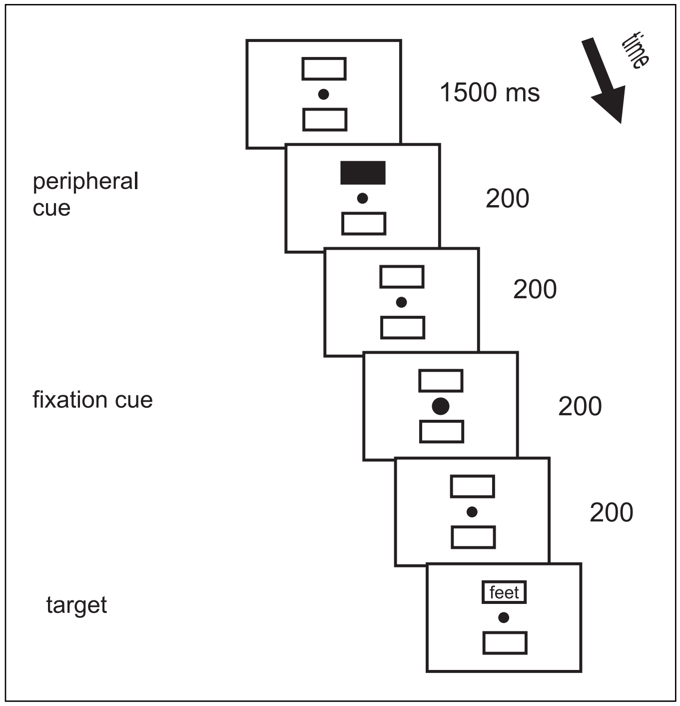

Fig. 1. Timing of the trial sequence. The target could appear above or below the fixation dot.

The Trial Type × Word Frequency interaction was also significant, $F(2, 18) = 7.53$, $MSE = 790$, $p < .005$. Inhibition was greatest for the low-frequency words (119 ms), and smaller for the high-frequency words (60 ms) and the nonwords (58 ms). Results of t tests revealed that the amount of inhibition for the low-frequency words was significantly different from the amount of inhibition for the high-frequency words ($p < .05$) and the nonwords ($p < .01$), but the amount of inhibition for the high-frequency words was not significantly different from the amount for the nonwords ($p > .05$).

To account for the large differences in response times for high- and low-frequency words and nonwords, we conducted a proportional analysis on the mean RTs. For each level of word frequency, the mean for the cued trials was divided by the mean for the uncued trials. Thus, greater numbers indicate more inhibition. A one-way ANOVA was conducted on the proportions as a function of word frequency. A significant main effect of word frequency was found, $F(2, 9) = 7.23$, $MSE = 0.003$, $p < .01$. Results of t tests revealed that there was proportionately more inhibition for the low-frequency words ($M = 1.15$) than for the nonwords ($M = 1.07$, $p < .01$) and high-frequency words ($M = 1.09$, $p < .05$). As was the case with mean RTs, the proportions for the high-frequency words and nonwords were not significantly different ($p > .05$).

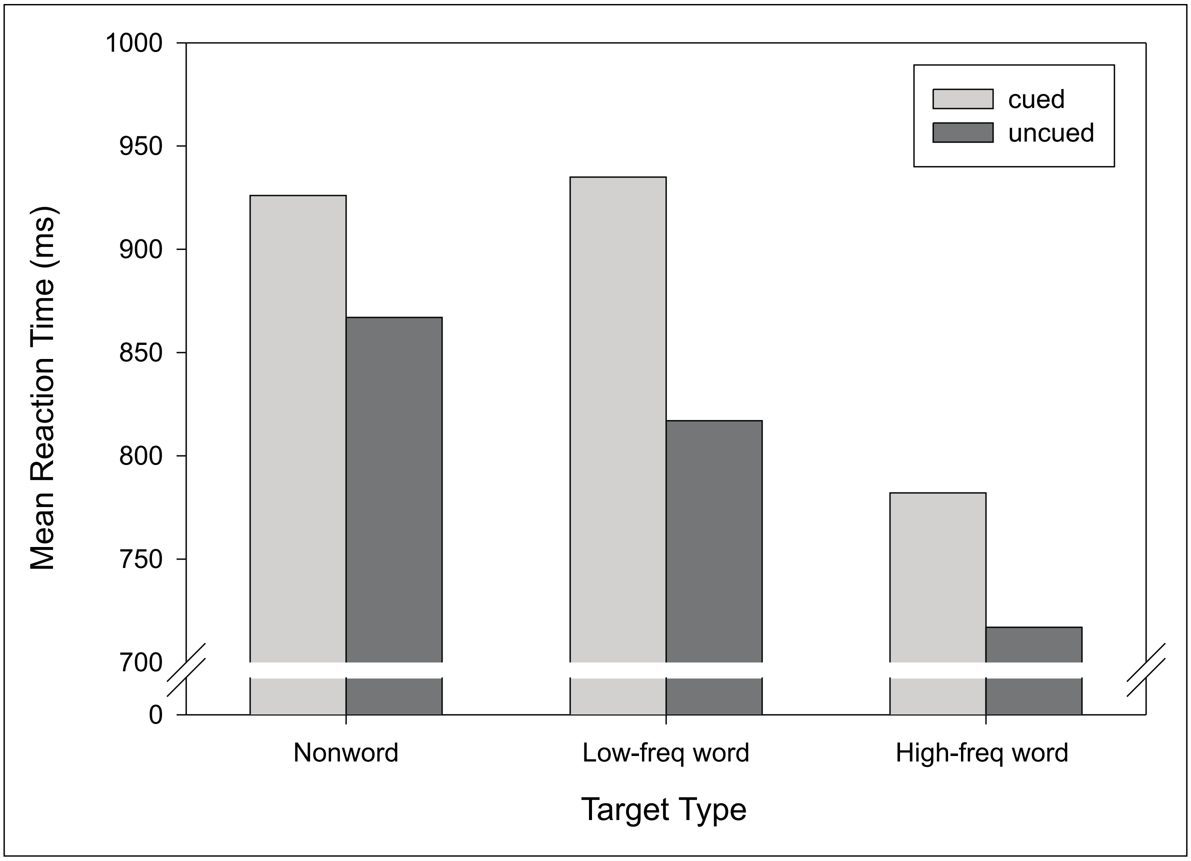

Fig. 2. Mean reaction times for the trials with correct responses in Experiment 1. Targets were either high-frequency ("High-freq") or low-frequency ("Low-freq") words or nonwords.

Errors

A 2 (trial type: cued vs. uncued) × 3 (word frequency: high-frequency word vs. low-frequency word vs. nonword) ANOVA was conducted on participants' error rates, which included both errors and outliers. Only a significant main effect of word frequency was observed, $F(2, 18) = 50.76$, $MSE = 13$, $p < .0001$; the greatest proportion of errors was observed for the low-frequency words (13.41%), followed by the nonwords (7.59%) and the high-frequency words (1.82%). There was no effect of trial type nor a Trial Type × Word Frequency interaction, both *F*s < 1. Thus, there was no speed-accuracy trade-off, as the fastest condition (high-frequency words) also yielded the fewest errors.

Summary

The results from Experiment 1 support the notion that inhibition of return can affect complex decisions such as word/nonword discriminations. Moreover, the results also indicate that inhibition of return differentially affects the time to recognize low-frequency words as compared with high-frequency words and nonwords. Thus, it appears that inhibition of return may affect lexical access. However, it is also possible that the findings from the present experiment were due to some aspect of the lexical decision task itself and not lexical access in general. Participants in lexical decision tasks are unable to locate nonwords in the lexicon. It might be that the present results were due to some difference between attempting to access words versus nonwords in the lexicon, rather than to the effects of high- versus low-frequency words. Examining the effects of inhibition of return and word frequency in a task in which the stimulus is always in the lexicon would provide further evidence that inhibition of return affects the process of lexical access.

EXPERIMENT 2

The purpose of Experiment 2 was to examine the effects of inhibition of return in a task that involved lexical access but not word/nonword discriminations. We chose to use a categorization task in which participants had to make discriminations between words that denoted either persons or inanimate things. As in the previous experiment, the words were either high or low in frequency. We expected that if inhibition of return does affect lexical access, the same Trial Type × Word Frequency interaction that was found in Experiment 1 would also be found in this categorization task, that is, that we would find greater inhibition of return for low-frequency words than for high-frequency words.

Method

Participants

Ten undergraduate students from the University of Toronto each participated in a single experimental session. They participated to fulfill a course requirement.

Materials

The stimulus set consisted of 48 high-frequency and 48 low-frequency words that were drawn from a list developed by Monsell, Doyle, and Haggard (1989). Of the 48 words in each frequency condition, 24 denoted persons (e.g., *aunt*, *clerk*) and 24 denoted inanimate things (e.g., *loft*, *radar*). Word frequency was based on the Kučera and Francis (1967) norms. The low-frequency words had counts less than 7 per million (for person words, M = 1.80 occurrences per million, range: 1–4; for thing words, M = 1.9 occurrences per million, range: 1–5). The high-frequency words had counts greater than 36 per million (for person words, M = 110 occurrences per million, range: 41–323; for thing words, M = 103 occurrences per million, range: 38–280). Word length ranged from four to six letters, and high- and low-frequency words were matched for length.

Apparatus and procedure

The same apparatus and procedure that were used in Experiment 1 were used in the present experiment. The only change was that the targets were now words that denoted either persons or things. Key-press responses were counterbalanced across participants. Half of the participants pressed the “z” key if the target denoted a person and pressed the “/” key if the target denoted an inanimate thing, whereas the other half of the participants pressed the opposite keys. Prior to the presentation of the test trials, participants completed a block of 20 practice trials.

Design

The single session consisted of one block of 192 trials. To increase the number of trials, we repeated each word once. The rest of the design was the same as in Experiment 1.

Results and Discussion

The same criteria used in Experiment 1 were used to check for errors and outliers in the present study. As before, all errors and outliers were excluded from the latency analyses.

Latencies

Figure 3 shows the mean RTs for the trials with correct responses. A 2 (trial type: cued vs. uncued) × 2 (word frequency: high-frequency vs. low-frequency words) × 2 (category type: person vs. thing) ANOVA was conducted on the mean RTs. There was a significant main effect for trial type, $F(1, 9) = 41.30$, $MSE = 901$, $p < .001$. Responses were slower in the cued (M = 871 ms) than in the uncued (M = 828 ms) condition. There was also a significant main effect for word frequency, $F(1, 9) = 35.38$, $MSE = 5{,}899$, $p < .001$. Responses to high-frequency words (M = 798 ms) were faster than responses to low-frequency words (M = 901 ms). A significant main effect for category type was also found, $F(1, 9) = 13.87$, $MSE = 4{,}458$, $p < .005$. Responses to words denoting persons (M = 821 ms) were faster than responses to words denoting inanimate things (M = 878 ms).

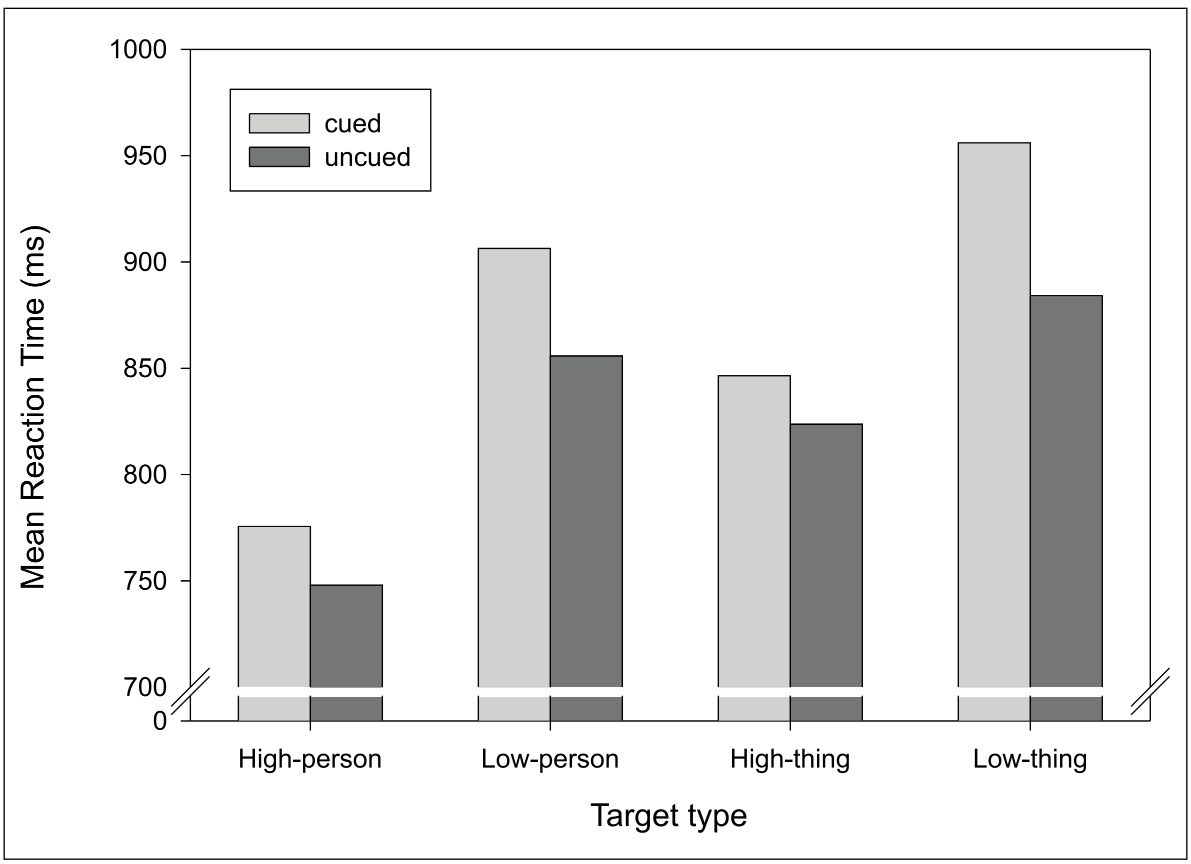

Fig. 3. Mean reaction times for the trials with correct responses in Experiment 2. Targets were high- and low-frequency words denoting persons and high- and low-frequency words denoting inanimate things.

There was also a significant Word Frequency × Category Type interaction, $F(1, 9) = 12.08$, $MSE = 484$, $p < .01$. Responses to high-frequency words denoting persons were much faster ($M = 762$ ms) than RTs to high-frequency words describing things ($M = 835$ ms), low-frequency words denoting persons ($M = 881$ ms), and low-frequency words denoting things ($M = 920$ ms).

Most important, there was a significant Trial Type × Word Frequency interaction, $F(1, 9) = 7.88$, $MSE = 828$, $p < .05$. As in Experiment 1, more inhibition was observed for responses to low-frequency words (61.25 ms) than responses to high-frequency words (25.15 ms). Neither the Category Type × Trial Type nor the Word Frequency × Category Type × Trial Type interaction was significant (ps > .05).

Similar results were obtained in the proportional analysis (cued RT divided by uncued RT). A 2 (word frequency: high vs. low) × 2 (category type: person vs. thing) ANOVA was conducted on the proportions. Only the main effect of word frequency was significant, $F(1, 9) = 6.76$, $MSE = 0.002$, $p < .05$, indicating that there was greater inhibition for the low-frequency words ($M = 1.07$) than for the high-frequency words ($M = 1.03$).

Errors

A 2 (trial type: cued vs. uncued) × 2 (word frequency: high-frequency vs. low-frequency word) × 2 (category type: person vs. thing) ANOVA was conducted on participants' error rates. There was a significant main effect for category type, $F(1, 9) = 8.31$, $MSE = 47$, $p < .05$. More errors were made in response to words denoting persons ($M = 10.13\%$) than in response to words denoting things ($M = 5.66\%$). There was also a main effect for word frequency, $F(1, 9) = 11.52$, $MSE = 97$, $p < .01$. More errors were made to low-frequency words ($M = 11.63\%$) than to high-frequency words ($M = 4.16\%$). Finally, there was a significant Word Frequency × Category Type interaction, $F(1, 9) = 25.08$, $MSE = 35$, $p < .01$. A higher percentage of errors was made to low-frequency words denoting persons ($M = 17.17\%$) than to low-frequency words denoting things ($M = 6.09\%$), or high-frequency words denoting persons ($M = 3.08\%$) or things ($M = 5.24\%$). It should be noted that several of the low-frequency person words were unusual and probably very unfamiliar to subjects (e.g., *lout, tsar, abbot, prefect*). Once again, there was no evidence of a speed-accuracy trade-off, as the fastest condition also yielded the fewest errors.

GENERAL DISCUSSION

The results of these studies are consistent with previous findings of inhibition of return in discrimination tasks (Pratt & Abrams, in press; Pratt et al., 1997). Specifically, we found inhibition of return in two separate identity-based choice decision tasks involving lexical access. The finding that RTs to targets at the cued locations were slower than RTs to targets at the uncued locations demonstrates that inhibition of return generalizes to complex choice decisions such as those involved in lexical decision and categorization tasks.

The significant Trial Type × Word Frequency interactions in the two experiments indicate that the amount of inhibition differed for high- and low-frequency words. The pattern of RTs for the uncued locations in Experiment 1 is consistent with previous word-frequency effects (Allen, Madden, & Slane, 1995), and reflects the results from a typical lexical decision task (i.e., responses to high-frequency words were the fastest, followed by responses to low-frequency words and then nonwords).

Of more interest is the fact that the amount of inhibition to the cued locations was much greater for the low-frequency words than for the high-frequency words. It may be that inhibition of return interferes with lexical processing, so that items that require more processing will show more inhibition. This notion is consistent with Balota and Chumbley's (1984) model of visual word recognition, which suggests that stimuli that have a moderate level of familiarity-meaningfulness require more analysis than those with a high level of familiarity-meaningfulness. Thus, in the present experiments, the low-frequency words required more processing, which resulted in more inhibition of return.

Other models of visual word recognition (for a review, see Allen et al., 1995) also suggest that additional processing is used for decisions about low-frequency words. In addition, Allen et al. (1995) suggested that letter-level processing is used for stimuli that are not immediately familiar. An extension of this idea is the possibility that in order to process a low-frequency word in a cued location, participants in the present experiments had to orient their attention to several locations within the cued area (i.e., to single letters or groups of letters in the box). It may be that movements of attention within a cued location, and not just movements of attention to cued locations, are also inhibited. In fact, there is evidence to indicate that inhibition of return tends to spread within cued target locations (Hartley & Kieley, 1995), as well as to areas beyond the location of a cue (Tassinari, Aglioti, Chelazzi, Marzi, & Berlucci, 1987).

At the moment, it is difficult to determine whether the differential amounts of inhibition of return found for the high- and low-frequency words were due to the relation between word frequency and inhibition of return or to inhibited movements of attention within the cued location. However, the present results clearly demonstrate that inhibition of return does generalize to complex choice decisions and that the inhibition may affect higher cognitive processes such as lexical access.

The present results join a growing accumulation of evidence that suggests inhibition of return may represent a general attentional phenomenon. One line of evidence is the considerable number of studies (including the present experiments) that have found inhibition of return in a range of discrimination tasks (e.g., Lupiáñez et al., 1997; Pratt, 1995; Pratt et al., 1997). Another line of evidence is the studies showing that inhibition of return is object-based, so that the inhibition tends to follow previously attended objects even if those objects move from the location at which they were first attended (e.g., Tipper, Driver, & Weaver, 1991; Tipper et al., 1994; Weaver, Lupiáñez, & Watson, in press; but see also Müller & von Mühlenen, 1996). A further line of evidence is work showing that inhibition of return not only occurs at a single previously attended location but may occur at several sequentially attended locations (e.g., Abrams & Pratt, 1996; Danziger, Kingstone, & Snyder, in press; Tipper, Weaver, & Watson, 1996).

It should be noted, however, that there have been failures to find inhibition of return in situations in which it might have been expected to be present. For example, temporal-order judgments, which are thought to be attentional in nature, are not affected by inhibition of return (e.g., Maylor, 1985; Posner & Cohen, 1984). A related phenomenon called illusory line motion also does not appear to be influenced by inhibition of return (Schmidt, 1996). Thus, although the present results clearly support the notion that inhibition of return reflects the output of a general attentional mechanism, it is also clear that more research will be required to determine the exact nature of this mechanism.

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