

# Negative priming and perceptual fluency: More than what meets the eye

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In two priming experiments, we manipulated the perceptual quality of the target or the distractor on the prime trial; the stimuli were repeated or novel. Negative priming was found to be contingent on stimulus repetition, because it was obtained with repeated items but not with novel items. Prime trial perceptual degradation modulated negative priming for repeated items but had no effect on priming in ignored repetition conditions using novel stimuli. These patterns were obtained even when the effect of perceptual degradation was (1) greater than the effect of stimulus repetition and (2) greater for novel words than for repeated words. Although stimulus repetition increases perceptual fluency, the activation of perceptual representations by itself is not sufficient to produce negative priming. Instead, we suggest that negative priming is a manifestation of an activation-sensitive inhibitory mechanism that functions to reduce response competition.

One of the most important aspects of human cognition is the ability to selectively process task relevant information while ignoring irrelevant information. Early research on this topic focused on the facilitation of task-relevant information, often appealing to *spotlight* (Broadbent, 1982; Posner, 1980) or *zoom lens* (Eriksen & St. James, 1986) metaphors. In these models, items that fall into the focus of attention receive additional processing, whereas information outside the focus of attention is assumed to passively decay. More recent theory suggests that selective attention involves both the facilitation of task relevant information and the *inhibition* of irrelevant information (e.g., Houghton & Tipper, 1994; Posner & Dehaene, 1994).

One of the most successful methods for studying the inhibitory mechanisms hypothesized to underlie selective attention involves the use of the negative priming paradigm (for reviews see Fox, 1995; May, Kane, & Hasher, 1995; Neill, Valdes, & Terry, 1995). In a typical negative priming task, trials are presented in successive pairs, called *couplets*. The first trial in the couplet is referred to as the *prime trial*, and the second trial is the *probe trial*. On each trial, two stimuli are presented and the participant is required to respond to one stimulus, the target, and ignore another stimulus, the distractor. In the critical *ignored repetition* condition, the prime trial distractor becomes the target on the probe trial. Relative to control

trials, performance is slower and less accurate on ignored repetition probe trials, defining the negative priming effect (Dalrymple-Alford & Budayr, 1966; Lowe, 1979; Neill, 1977; Tipper, 1985).

Negative priming has been observed with a variety of stimuli, including letters (Tipper & Cranston, 1985), words (Malley & Strayer, 1995), objects (Tipper, 1985), and nonsense shapes (DeSchepper & Treisman, 1996). The effect has also been obtained using a variety of tasks, including matching (DeSchepper & Treisman, 1996; Neill, Lissner, & Beck, 1990), naming (Strayer & Grisson, 1999a), reaching (Tipper, Lortie, & Baylis, 1992), localization (Tipper, Brehaut, & Driver, 1990), and categorization (Tipper & Driver, 1988). Finally, negative priming has been found with both manual responses and verbal responses. Thus, negative priming appears to reflect a general property of selective attention.

Although there is general agreement concerning the robustness of the negative priming effect, there is less of a consensus about the mechanisms that underlie negative priming. Several models explain these mechanisms primarily from the perspective of processes engaged during the probe trial, such as mismatch (e.g., MacDonald, Joordens, & Seergobin, 1999; Park & Kanwisher, 1994) or memory retrieval (Milliken, Joordens, Merikle, & Seifert, 1998; Neill & Mathis, 1998; Neill, Valdes, Terry, & Gorfein, 1992). We will defer discussion of these models until the General Discussion section. The primary purpose of the present study was to address issues raised by a specific group of models, generally termed *distractor inhibition* (e.g., Houghton & Tipper, 1994; Houghton, Tipper, Weaver, & Shore, 1996; Malley & Strayer, 1995;

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Neill, 1977; Strayer & Grison, 1999a; Tipper, 1985). In these models, it is proposed that the internal representations of distractor stimuli are inhibited to facilitate task-relevant actions. Furthermore, the effects of distractor inhibition on the prime trial are thought to carry over into the processing of the probe trial, thereby producing the negative priming effect. However, this account leaves unanswered questions about the precise nature of the distractor inhibition as well as about the locus of the inhibitory mechanisms hypothesized to underlie negative priming.

Houghton and Tipper (1994; Houghton et al., 1996) developed a computational model of selective attention in which reactive inhibitory mechanisms selectively act on representations activated by distractor input. In their model, a match–mismatch detector integrates top-down information defined by the behavioral goals of the observer, with bottom-up information generated from external inputs. The match–mismatch detector acts as a self-adjusting gain control mechanism in which excitatory and inhibitory feedback and the external input all contribute to the activation of the perceptual representations. Thus, over time, the perceptual activation of target and distractor representations are differentiated so that activation is greater for targets than for distractors. These patterns of perceptual activation are fed forward to a response system that is responsible for binding them to response schemata and for generating a response.<sup>1</sup>

Because the inhibitory feedback from the match–mismatch detector is proportional to the perceptual activation of the distractor representation, Houghton et al. (1996) reasoned that negative priming should increase as the activation level of the distractor representation increases. In simulations, they found that a highly activated distractor was inhibited more than a weakly activated distractor (cf. Houghton et al., 1996, Figure 6). In an experiment using a location-based variant of negative priming, modest support for these predictions was obtained. With a black background, more negative priming was found with a high-contrast white distractor (34 msec) than with a low-contrast gray distractor (27 msec), although this difference was not reliable. Thus, it appears that “ignored inputs achieving higher levels of activation may actually be subject to greater levels of inhibition” (Houghton et al., 1996, p. 157).

However, the story of perceptual inhibition is made more complicated by research showing that active perceptual representations are not the only locus of inhibition, nor are they always inhibited. For example, Tipper and Driver (1988) found that negative identity priming persisted from pictures to words (e.g., when the prime distractor was a line drawing of a dog and the probe target was the word DOG) and vice versa. They concluded that the perceptual information pertaining to the line drawing, or to the written word, were not suppressed because negative priming remained even when the same semantic information was presented in a different percep-

tual form. Instead, they hypothesized that inhibitory mechanisms act on abstract categorical representations of distractors. Furthermore, evidence from recent event-related brain potentials (ERP) studies suggests that highly active perceptual representations are not inhibited in a negative priming task involving word naming (Strayer & Grison, 1999a, 1999b). That is, there was no ERP evidence for perceptual inhibition in the trials in which behavioral negative priming was observed. As with Tipper and Driver’s research, this result suggests a later, post-perceptual locus of inhibition.

Meanwhile, other research has found negative priming to be contingent on stimulus repetition (e.g., Malley & Strayer, 1995; Strayer & Grison, 1999a). For example, Strayer and Grison found negative priming with stimuli that were repeated throughout the experiment, but negative priming was never obtained with experimentally novel stimuli. Strayer and Grison (1999a) suggested that these stimulus repetition effects reveal a mechanism that is reactive to the level of activation of the distractor and functions to reduce response competition. However, because repetition is thought to activate multiple internal representations of the distractor, ranging from low-level perceptual features to abstract semantic codes to specific motor responses, it is unclear which of these modulated negative priming.

Recent research also suggests that a straightforward response inhibition explanation of negative priming is overly simplistic. For example, Neill et al. (1990) examined negative priming in a same–different flanker task. The negative priming effect did not depend on whether the response in the prime or probe trial was *same* or *different*. Instead, it seemed as though distractor representations were suppressed from reaching the response execution system. In a similar study, Tipper, MacQueen, and Brehaut (1988) also found that negative priming in a flanker task survived, regardless of whether the response on the prime and probe required verbal naming of the letter or a keypress to identify the letter. These findings also suggest that inhibition is not isolated in the response execution system. Tipper et al. (1988) concluded that inhibition probably occurs at a central level, where perceptual information and response information for a stimulus are integrated.

The purpose of the present study was to further examine the effects of distractor activation on negative priming and to determine how activation of different internal representations modulates the effect. One way to interpret the effect of stimulus repetition on negative priming (e.g., Malley & Strayer, 1995; Strayer & Grison, 1999a) is to assume that repetition activates multiple representations of the stimulus. When repeated stimuli appear as distractors, the higher level of activation of the internal representations of these stimuli may lead to greater inhibition. According to this interpretation, stimulus repetition is only one of many ways to increase the perceptual fluency of irrelevant information. Therefore, according to

this interpretation, it may be possible to obtain negative priming with novel stimuli if the perceptual fluency of novel distractors is sufficiently intense.

Alternatively, activation of postperceptual representations may be critical for negative priming. For example, Tipper's (1985) response blocking interpretation of negative priming suggests that the internal representations of distractors remains active while being blocked from access to response mechanisms (see also Tipper & Cranston, 1985). In addition, Strayer and colleagues (Malley & Strayer, 1995; Strayer & Grison, 1999a) have proposed that negative priming is a manifestation of processes engaged to reduce response competition. These inhibitory mechanisms are hypothesized to be engaged only when irrelevant information is in a highly activated state and competes with selecting and responding to task-relevant information. Therefore, if the activation of postperceptual representations is necessary for negative priming, then the manipulation of perceptual fluency should have little effect on negative priming if novel stimuli are used.

## EXPERIMENT 1

In Experiment 1, we utilized an identity priming task in which subjects named one of two words that were presented in the display. Perceptual fluency was manipulated by degrading either the prime target or the prime distractor. In addition, stimulus repetition was manipulated by presenting both novel and repeated words in the experiment. If activation of perceptual representations is sufficient to produce negative priming, it should be possible to obtain negative priming with both novel and repeated stimuli if the perceptual fluency of the distractor is sufficiently intense. By contrast, if activation of postperceptual representations is necessary to produce negative priming, negative priming should depend on stimulus repetition. Finally, there may be an interactive relationship so that manipulations that affect perceptual fluency modulate the influence of stimulus repetition. In the latter case, we predict that negative priming will be greatest when both the perceptual and postperceptual representations of the distractor are highly activated.

### Method

**Participants.** Forty University of Utah undergraduates (21 female and 19 male), ranging in age from 18 to 25, with a mean age of 21.1 years, participated in the experiment for research credit. All of the participants had normal color vision (Ishihara, 1993), reported normal or corrected-to-normal visual acuity, and were native English speakers.

**Stimuli and Apparatus.** The stimuli were 1,056 four to seven letter words, 264 words of each length, selected from the Kučera and Francis (1967) word norms. The word frequencies ranged between 1 and 145 occurrences per million. The *repeated stimulus set* was composed of 16 words, 4 of each letter length. The remaining 1,040 stimuli formed the *novel stimulus set*. The assignment of words to repeated or novel stimulus sets was randomized across participants.

The experiment was performed on an IBM-compatible computer with a Viewsonic 6 superVGA monitor. On each trial, the stimuli were presented on a black background above and below a white

central fixation cross. Each word subtended an approximate visual angle of 0.5° vertically and 1.7°–2.6° horizontally. The entire stimulus array subtended an approximate visual angle of 1.2° vertically and 1.7°–2.6° horizontally. The latency of participants's verbal responses was measured using a voice-activated response device, and response accuracy was manually recorded by the experimenter.

**Procedure.** Each participant was tested in a 1-h session comprising 1,248 trials. A trial consisted of a target word presented in blue (or green) and a distractor word presented in green (or blue). The color of the targets and distractors was counterbalanced across participants. On each trial, a target word was presented above (or below) the fixation point and a distractor word of equal letter length appeared in the opposite location. Targets appeared in the top location on half of the trials and in the bottom location on the remaining trials. The target and distractor words remained in view for 150 msec. The participants were required to name the target word aloud as quickly and accurately as possible. A 10-sec break was provided every 100 trials to prevent fatigue.

There were 624 prime–probe couplets in the experiment. One-third of these were ignored repetition couplets in which the prime distractor became the probe target. One-third were attended repetition couplets in which the prime target was also the probe target. The remaining third were control couplets in which the prime and the probe trials shared no words in common. For each of these couplet types, half of the trials used novel words that were presented, at most, twice in the experiment. The remaining trials used repeated words that were presented an average of 78 times in the experiment.

Perceptual fluency was manipulated by degrading either the prime target word or the prime distractor word. Perceptual degradation was accomplished by removing 20% of the pixels from the target or distractor word. Similar manipulations have been used to study perceptual fluency in positive priming (e.g., Feustel, Shiffrin, & Salasoo, 1983; Hawley & Johnston, 1991); however, unlike these earlier studies, the number of pixels removed from a stimulus remained constant throughout the trial. Probe trial stimuli were always perceptually intact.

**Design and Analysis.** The experimental design was a  $3 \times 2 \times 2$  (couplet type: [ignored repetition, attended repetition, and control]  $\times$  repetition: [novel vs. repeated]  $\times$  degradation: [prime target degraded vs. prime distractor degraded]) factorial. The order of the conditions was randomized so that conditions could not be predicted in advance.

Analyses were conducted on the reaction times (RT) and error rate data using a  $3 \times 2 \times 2$  repeated-measures analysis of variance (ANOVA). Priming difference scores were obtained by comparing performance on the ignored or attended repetition probe trial with the corresponding control probe trial. These difference scores were analyzed in separate  $2 \times 2$  (repetition: [novel vs. repeated]  $\times$  degradation: [prime target degraded vs. prime distractor degraded]) repeated-measures ANOVAs. All planned comparisons were performed using one-tailed *t* tests. A significance level of  $p < .05$  was adopted for all inferential tests.

### Results and Discussion

The mean prime trial RT and error rates are presented in Table 1. An analysis of performance on the prime trial revealed that participants responded more rapidly to repeated words than to novel words [ $F(1,39) = 271.1$ ,  $MS_e = 782$ ,  $p < .01$ ] and more rapidly when the distractor was degraded than when the target was degraded [ $F(1,39) = 22.8$ ,  $MS_e = 287$ ,  $p < .01$ ]. These two factors interacted, indicating that the effect of perceptual degradation was greater for novel words than for repeated words [ $F(1,39) = 5.6$ ,  $MS_e = 190$ ,  $p < .03$ ]. An identical pattern of prime trial effects was obtained with the error

**Table 1**  
**Experiment 1 Means and Standard Deviations for**  
**Prime Trial Reaction Time (RT) and Error Rates (ER)**  
**as a Function of Degradation and Repetition**

	Target Degraded				Distractor Degraded			
	RT		ER		RT		ER	
	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>
Novel	705	76	10.2	7.1	688	81	3.6	3.2
Repeated	628	63	2.2	2.4	620	65	1.1	3.4

rate data. Participants made fewer errors when responding to repeated words than to novel words [ $F(1,39) = 51.2$ ,  $MS_e = 21$ ,  $p < .01$ ] and when the distractor was degraded than when the target was degraded [ $F(1,39) = 37.8$ ,  $MS_e = 16$ ,  $p < .01$ ]. In addition, the effect of perceptual degradation was greater for novel words than for repeated words [ $F(1,39) = 40.2$ ,  $MS_e = 8$ ,  $p < .01$ ].

The mean probe trial RT, error rates, and difference scores are presented in Table 2. Participants responded more rapidly to repeated words than to novel words [ $F(1,39) = 149.5$ ,  $MS_e = 1,395$ ,  $p < .01$ ], and repetition modulated the effects of priming and perceptual degradation. In particular, the ignored repetition condition yielded reliable negative priming only for repeated words [ $F(1,39) = 26.3$ ,  $MS_e = 605$ ,  $p < .01$ ]. Planned comparisons indicated that perceptual degradation had absolutely no effect on performance in the ignored repetition conditions using novel words. However, perceptual degradation did modulate negative priming obtained in the ignored repetition conditions using repeated words. In these cases, negative priming was greater when the prime

trial distractor was perceptually intact than when the prime trial distractor was perceptually degraded.

If activation of perceptual representations is sufficient to produce negative priming, we should have found negative priming with perceptually fluent novel distractors. However, negative priming was never obtained with novel stimuli, even though the prime trial data indicate that the effect of perceptual degradation was actually greater for novel words than for repeated words. Thus, activation of perceptual representations appears to be insufficient to engage the mechanisms underlying negative priming. Because negative priming was obtained only with repeated stimuli, this implies that the mechanisms underlying negative priming act on active postperceptual representations. In addition, because perceptual degradation modulated negative priming when repeated stimuli were used, this suggests that the activation of earlier perceptual representations propagates to later response-based representations.

Positive priming in attended repetition conditions was also modulated by stimulus repetition and perceptual degradation. In particular, there was considerable positive priming obtained with novel words, but priming was negligible for repeated words [ $F(1,39) = 113.3$ ,  $MS_e = 972$ ,  $p < .01$ ]. The effects of repetition are consistent with prior observations from the repetition priming literature showing that positive priming diminishes with repetition (e.g., Logan, 1990; Malley & Strayer, 1995; Strayer & Grison, 1999a). In addition, planned comparisons indicated that perceptual degradation modulated positive priming so that priming was greater when the target was easier to see on the prime trial.

**Table 2**  
**Experiment 1 Means and Standard Deviations for Probe Trial Reaction Time (RT),**  
**Difference Scores (DS), and Error Rate (ER) as a Function of**  
**Degradation, Repetition, and Couplet Type**

	RT		DS		ER		DS	
	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>
Target Degraded								
Novel words								
Control	651	76	–	–	1.4	1.9	–	–
Ignored repetition	647	74	4	29	2.6	3.0	–1.2*	3.2
Attended repetition	609	64	42*	35	1.4	1.9	0.0	2.4
Repeated words								
Control	584	64	–	–	0.4	0.9	–	–
Ignored repetition	604	59	–20*	26	0.8	1.8	–0.4	2.0
Attended repetition	592	63	–8*	22	0.8	2.1	–0.4	2.3
Distractor Degraded								
Novel words								
Control	679	78	–	–	3.6	3.6	–	–
Ignored repetition	675	77	4	24	2.6	3.4	1.0*	3.1
Attended repetition	618	65	61*	33	0.8	1.6	2.8	2.9
Repeated words								
Control	614	66	–	–	0.2	0.7	–	–
Ignored repetition	626	65	–12*	29	0.8	2.1	–0.6	2.2
Attended repetition	608	64	6	33	0.5	1.2	–0.3	1.4

Note—A difference score of zero reflects no priming, a negative difference reflects negative priming, and a positive difference reflects positive priming. \* $p < .05$ .

**Table 3**  
**Experiment 2 Means and Standard Deviations for**  
**Prime Trial Reaction Time (RT) and Error Rates (ER)**  
**as a Function of Degradation and Repetition**

	Target Degraded				Distractor Degraded			
	RT		ER		RT		ER	
	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>
Novel	856	104	8.8	4.8	714	102	1.6	1.7
Repeated	723	103	2.1	1.9	652	90	0.8	1.0

## EXPERIMENT 2

Experiment 1 demonstrated that negative priming is primarily influenced by stimulus repetition but that it can also be modulated by the perceptual fluency of repeated distractors. However, one limitation of Experiment 1 is that the magnitude of the perceptual degradation effect was relatively small when compared with the magnitude of the stimulus repetition effect. The purpose of Experiment 2 was to make the manipulations of perceptual degradation and stimulus repetition more comparable in magnitude. This was accomplished by increasing the number of pixels removed from the degraded stimulus and by decreasing the number of times that a stimulus from the repeated set was repeated in the experiment.

### Method

**Participants.** Forty University of Utah undergraduates (27 female and 13 male), ranging in age from 18 to 29, with a mean age of 20.4 years, participated in Experiment 2 for research credit. All of the participants had normal color vision (Ishihara, 1993), reported normal or corrected-to-normal visual acuity, and were native English speakers.

**Stimuli and Apparatus.** The stimuli and apparatus were identical to those of Experiment 1, with the following exceptions. The stimuli were 1,100 four to seven letter words, 275 words of each length, selected from the Kučera and Francis (1967) word norms. The *repeated stimulus set* was 20 words, 5 of each word length. The remaining 1,080 stimuli formed the *novel stimulus set*.

**Procedure, Design, and Data Analysis.** The procedure, design, and data analysis were identical to that of Experiment 1, with the following exceptions. Each participant was tested in a 1-h session composed of 1,296 trials. The target and distractor words remained on the computer monitor until the subject responded or for a maximum of 2,500 msec. There were 648 prime-probe couplets in the experiment. One-third of these were ignored repetition couplets, one-third were attended repetition couplets, and the remaining third were control couplets. For each couplet type, half of the trials used novel words that were presented, at most, twice in the experiment. The remaining trials used repeated words that were presented an average of 65 times in the experiment. Finally, on half of the trials in the experiment, the prime trial target word was degraded, and, on the remaining trials, the prime trial distractor word was degraded. Degradation was accomplished by removing 35% of the pixels from the target or distractor word. As in Experiment 1, the probe stimuli were always perceptually intact.

### Results and Discussion

The mean prime trial RT and error rates are presented in Table 3. An analysis of performance on the prime trial indicated that participants responded more rapidly to re-

peated words than to novel words [ $F(1,39) = 435.5$ ,  $MS_e = 873$ ,  $p < .01$ ]. Participants also responded more rapidly when the distractor was degraded than when the target was degraded [ $F(1,39) = 401.2$ ,  $MS_e = 1,116$ ,  $p < .01$ ]. Note that the effect of perceptual degradation was slightly larger than the effect of stimulus repetition (106 vs. 98 msec, respectively). The effects of stimulus repetition and perceptual degradation interacted, revealing a greater effect of degradation for novel words than for repeated words [ $F(1,39) = 159.5$ ,  $MS_e = 313$ ,  $p < .01$ ]. An identical pattern of prime trial effects was obtained with the error rate data. Participants made fewer errors when responding to repeated words than to novel words [ $F(1,39) = 89.3$ ,  $MS_e = 6$ ,  $p < .01$ ]. In addition, participants also made fewer errors when the distractor was degraded than when the target was degraded [ $F(1,39) = 103.3$ ,  $MS_e = 7$ ,  $p < .01$ ]. These two effects also interacted so that the effect of perceptual degradation was greater for novel words than for repeated words [ $F(1,39) = 69.4$ ,  $MS_e = 5$ ,  $p < .01$ ].

The mean probe trial RT, error rates, and difference scores are shown in Table 4. Participants responded more rapidly to repeated words than to novel words [ $F(1,39) = 133.5$ ,  $MS_e = 1,681$ ,  $p < .01$ ]. Repetition modulated both the effects of priming and perceptual degradation. The ignored repetition condition yielded negative priming only for repeated words [ $F(1,39) = 6.3$ ,  $MS_e = 1,242$ ,  $p < .02$ ]. Planned comparisons revealed that perceptual degradation did not affect performance in the ignored repetition conditions using novel words. However, perceptual degradation did modulate negative priming in the ignored repetition conditions using repeated words. In the latter condition, negative priming was greater when the prime-trial distractor was perceptually intact than when the prime-trial distractor was perceptually degraded.

As in Experiment 1, positive priming in attended repetition conditions was also modulated by stimulus repetition and perceptual degradation. In particular, there was considerable positive priming obtained with novel words, but priming was negligible for repeated words [ $F(1,39) = 62.4$ ,  $MS_e = 2,131$ ,  $p < .01$ ]. In addition, planned comparisons indicated that perceptual degradation modulated positive priming so that priming was greater when the target was easier to see on the prime trial.

Experiment 2 replicated and extended the pattern of data obtained in Experiment 1. Negative priming was modulated by perceptual degradation only if repeated stimuli were used. Negative priming was never obtained with novel stimuli, regardless of distractor perceptibility. These patterns were obtained even though the effect of prime trial degradation was (1) greater than the effect of stimulus repetition and (2) greater for novel words than for repeated words. These data imply that the activation of perceptual representations is not sufficient to engage the mechanisms underlying negative priming. Although stimulus repetition increases perceptual fluency, it appears that activation of later postperceptual representations are necessary to produce negative priming.

**Table 4**  
**Experiment 2 Means and Standard Deviations for Probe Trial Reaction Time (RT),**  
**Error Rate (ER), and Difference Scores (DS) as a Function of**  
**Degradation, Repetition, and Couplet Type**

	RT		DS		ER		DS	
	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>
Target Degraded								
Novel words								
Control	715	98	–	–	1.8	2.5	–	–
Ignored repetition	707	98	8	40	1.3	2.4	0.5	3.0
Attended repetition	659	85	56*	47	1.4	2.0	0.4	3.0
Repeated words								
Control	647	94	–	–	0.3	0.9	–	–
Ignored repetition	660	95	–13*	26	0.7	1.6	–0.4	1.8
Attended repetition	639	86	8*	26	0.7	1.4	–0.4	1.6
Distractor Degraded								
Novel words								
Control	708	103	–	–	1.6	2.5	–	–
Ignored repetition	705	104	3	34	0.9	2.4	0.7	2.7
Attended repetition	637	84	71*	53	0.9	1.2	0.7	3.0
Repeated words								
Control	641	95	–	–	0.6	1.3	–	–
Ignored repetition	646	93	–5	27	1.0	2.0	–0.4	2.1
Attended repetition	638	95	3	34	0.9	1.8	–0.3	1.9

Note—A difference score of zero reflects no priming, a negative difference reflects negative priming, and a positive difference reflects positive priming. \* $p < .05$ .

## GENERAL DISCUSSION

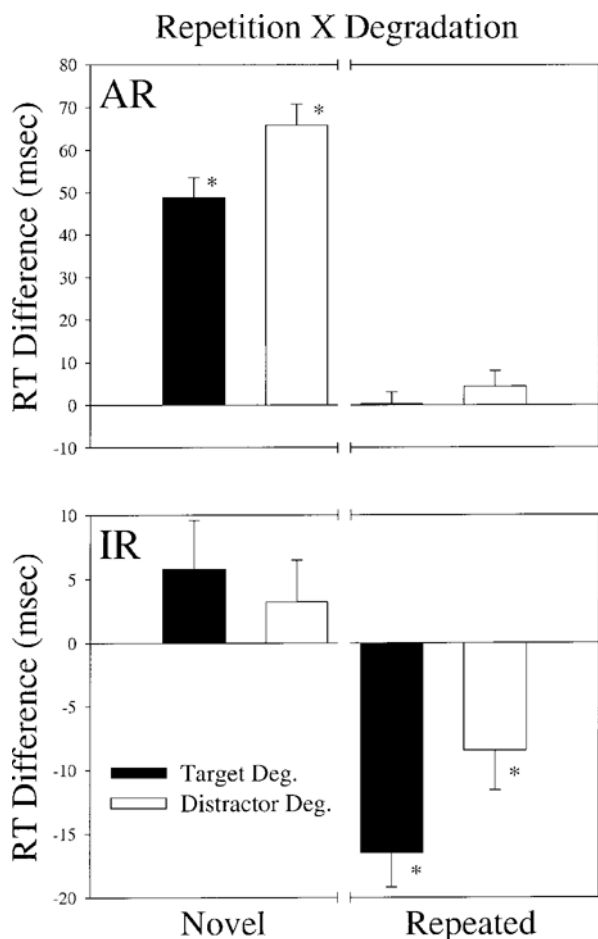
Figure 1 presents the priming data aggregated across Experiments 1 and 2. Negative priming was found only in ignored repetition conditions using repeated stimuli. When novel stimuli were used in these same conditions, a trend towards positive priming was observed. Positive priming was obtained in attended repetition conditions using novel stimuli; however, priming was negligible in these same conditions when repeated stimuli were used. In the latter case, repetition appears to have chronically primed these items, leaving little room for improvement. Importantly, it was only when the representations were in a highly activated state that negative priming was obtained. Together, these findings replicate and extend the prior findings, demonstrating that negative priming is dependent on stimulus repetition (Malley & Strayer, 1995; Strayer & Grison, 1999a).

Perceptual degradation modulated negative priming when repeated stimuli were used, but had no effect on priming in ignored repetition conditions when novel stimuli were used. This pattern held, even though the effect of perceptual degradation was greater for novel than for repeated words and was also true even when the effect of perceptual degradation was equivalent in magnitude to the effect of stimulus repetition. The manipulation of perceptual degradation also modulated the positive priming obtained with novel words in attended repetition conditions so that positive priming was greater when the prime target was more perceptually salient than when it was perceptually degraded.

It is interesting that perceptual degradation had qualitatively different effects when items were novel or re-

peated. We hypothesize that, in attended repetition conditions using novel stimuli, the change in the activation of the internal representations of the target from the prime to the probe trial is large, resulting in substantial facilitation. Moreover, increasing the perceptability of the target is likely to produce even greater increases in the activation of perceptual representations and thereby lead to greater levels of facilitation. By contrast, in attended repetition conditions using repeated stimuli, we hypothesize that the difference in the activation of the internal representations from the prime to the probe trial is small, and, therefore, little or no facilitation is observed. Furthermore, because the activation of these representations is likely to be close to ceiling, an increase in the perceptability of the target is unlikely to produce changes in the activation of these perceptual representations. Importantly, it is only when the internal representations of the prime trial distractor have been primed close to saturation levels that negative priming is obtained.

These findings further our understanding of the mechanisms underlying negative priming. In particular, the experiments reported in this article demonstrate that the magnitude of negative priming is determined by the level of activation of the distractor. This follows because negative priming using repeated stimuli was greater when the prime trial distractor was more perceptually fluent. The data also indicate that manipulations affecting the quality of the perceptual input did not have a direct impact on negative priming, because perceptual degradation did not modulate negative priming with novel stimuli (despite the fact that the effects of perceptual degradation were greater for novel stimuli). However, perceptual degradation appears to have an indirect effect on negative



**Figure 1.** The aggregated data from Experiments 1 and 2. The reaction time difference scores are plotted as a function of priming condition, repetition, (novel vs. repeated) and degradation (target degraded vs. distractor degraded). The top panel presents the attended repetition priming conditions and the bottom panel presents the ignored repetition priming conditions. In attended repetition conditions, reliable positive priming was obtained only with novel items and the positive priming effect was greater when the distractor was degraded than when the target was degraded. In ignored repetition conditions, reliable negative priming was obtained only with repeated items and the negative priming effect was greater when the target was degraded than when the distractor was degraded. AR refers to attended repetition, and IR refers to ignored repetition.

priming if postperceptual representations of the distractor have been activated through prior response. In the remainder of the article, we consider how these data bear on several theoretical perspectives of negative priming.

### Distractor Inhibition

Distractor inhibition models of negative priming (e.g., Houghton & Tipper, 1994; Houghton et al., 1996; Malley & Strayer, 1995; Neill, 1977; Strayer & Grison, 1999a; Tipper, 1985) propose that one or more of the internal representations of the distractor are inhibited to facilitate task-relevant actions. According to this perspective, negative priming is the result of residual inhibition that

carries over into the processing of the probe trial. Moreover, the level of inhibition is thought to vary as a function of the level of activation of the distractor. The data reported in this article are in general agreement with the notion of reactive inhibition, at least with repeated stimuli (i.e., negative priming was greater when the prime trial distractor was more perceptually fluent). However, because negative priming was not modulated by perceptual degradation using novel stimuli, this suggests that the activation of perceptual or object-based representations is not sufficient to produce negative priming. Because negative priming was modulated by perceptual degradation only when stimuli had been responded to on many occasions, this suggests that activation of later response-based representations is necessary for negative priming. Such an interpretation is consistent with the hypothesis that negative identity priming is a manifestation of an activation-sensitive inhibitory mechanism that functions to reduce response competition on the prime trial. These data are also in line with earlier observations by Strayer and Grison (1999a) that prior repetition as a target, but not as a distractor, is critical for negative priming. Target repetition is likely to activate many internal representations; however, the present data suggest that it is the activation of later response-based representations that is critical for negative priming.

The finding that activation of perceptual representations is not sufficient for negative priming appears to be problematic for the computational model developed by Houghton and Tipper (1994; Houghton et al., 1996, but see Note 1). This follows, given that the model postulates that the level of inhibition is directly related to the level of perceptual activation (cf. Houghton et al., 1996, Equation 3 and Figure 2) and that this inhibition is applied to object field representations (i.e., representations of grouped percepts; cf. Houghton et al., 1996, Figure 1). However, the model provides a straightforward account of the reactive nature of distractor inhibition and could be easily amended so that the level of inhibition is not directly determined by perceptual activation and that inhibition is not applied to early perceptual representations, but rather to later response-based representations. Such modification would be compatible with earlier *response blocking* interpretations of negative priming (e.g., Tipper, 1985; Tipper & Cranston, 1985).

### Episodic Retrieval

Neill and colleagues (Neill & Mathis, 1998; Neill & Valdes, 1992; Neill et al., 1992) developed a memory-based account of negative priming that attributes the effect to a form of proactive interference. According to the *episodic retrieval model*, each trial cues the retrieval of past instances involving similar stimuli and this retrieved information is hypothesized to reinstate similar processing on the current trial. If the retrieved episodic trace includes information that the stimulus was ignored, processing of the current stimulus is slowed.

Strayer and colleagues (Malley & Strayer, 1995; Strayer & Grison, 1999a) have argued that stimulus repetition

effects are problematic for the episodic retrieval model. With novel ignored repetition couplets, the only (and most recent) episodic information to be retrieved on the probe trial contains information that the target was previously ignored. By contrast, repeated ignored repetition probes should cue the retrieval of both compatible and incompatible instances. The precise effect of retrieving multiple traces depends on the processing assumptions of the model. One possibility is that the compatible and incompatible instances may be aggregated and cancel (if stimuli appear equally often as targets and distractors). Another possibility is that the most recent or fastest instance governs performance. In either case, the episodic retrieval model predicts as much, if not more, negative priming with novel items as with repeated items. This prediction is at odds with the data. Furthermore, Strayer and Grison (1999a) repeated a previously novel distractor from one to five times before presenting the stimulus as a target to increase the number of incompatible episodes available for retrieval; however, negative priming was not obtained in any of these conditions. By contrast, negative priming was found to increase as a function of the number of times that a stimulus was presented as a target before the ignored repetition couplet. Again, these effects are problematic for the episodic retrieval model.<sup>2</sup>

At first glance, the effects of perceptual degradation appear to be consistent with the episodic retrieval model. It is not unreasonable to assume that the trace of a perceptually intact distractor is more likely to be retrieved, and thereby produce more interference than a perceptually degraded distractor. But, given that the effects of perceptual degradation were greater for novel items than for repeated items, the episodic retrieval model would seem to predict that this manipulation would have a greater modulatory effect on negative priming in novel than in repeated conditions. Thus, it appears that episodic retrieval fails on two key predictions: the effect of stimulus repetition and the effect of perceptual degradation.

### Temporal Discrimination

Milliken et al. (1998) developed an alternative account of negative priming that incorporates both a fast, automatic memory retrieval and a slower perceptual analysis of the stimulus. According to the *temporal discrimination* interpretation, performance on control trials is thought to involve the slower perceptual analysis of the stimulus, whereas performance on attended repetition probe trials is thought to reflect the faster automatic memory retrieval. Negative priming is hypothesized to occur because the familiarity of the previously ignored distractor precludes a categorization of “new,” but is also insufficient for a categorization of “old.” This ambiguity in processing is thought to result in the slowing of behavior observed in ignored repetition conditions. There are, however, several unresolved issues regarding the temporal discrimination model. For example, it is not clear exactly what is being “retrieved” by the presentation of the probe trial, nor is it clear if only the most recent trial is

retrieved from memory or if multiple instances are retrieved. It is also not clear how or why automatic memory retrieval processes interfere with the slower perceptual analysis of the stimulus. Also unclear is why control trials using repeated items would not suffer from the temporal ambiguity (which would result in smaller differences between the control and ignored repetition conditions for repeated items than for novel items). Furthermore, it is unclear exactly how this form of memory retrieval differs from residual activation of internal representations persisting from the preceding trial.

The present results may also prove challenging for the temporal discrimination model. For example, if only the most recent trial is retrieved from memory, the temporal discrimination model would seem to predict equivalent negative priming for novel and repeated stimuli. That is, there is no a priori mechanism for why there should be greater ambiguity for repeated items than for novel items. If more than the most recent instance is retrieved from memory, repeated control trials should also suffer from this ambiguity, and the result should be smaller negative priming for repeated than novel items. Finally, the effects of perceptual degradation would suggest that more perceptually fluent prime trial distractors result in greater temporal ambiguity on the probe trial. However, given that the effect of perceptual degradation was greater for novel items than for repeated items, this would predict that this manipulation would have a greater modulatory effect on negative priming with novel than with repeated items.

In summary, the data indicate that negative priming is dependent on the activation of postperceptual representations of the distractor, in general agreement with activation-sensitive distractor inhibition models of negative priming. We suggest that negative priming is a manifestation of processes engaged on the prime trial to facilitate task-relevant actions by reducing the response competition of active but irrelevant distractor information. Thus, there is more to negative priming than what meets the eye—activation of postperceptual representations is necessary to produce the effect. Finally, it may be possible that other models of negative priming could account for the effects reported in this article; however, with the notable exception of Houghton and Tipper (1994), the extant models do not articulate their processing assumptions in sufficient detail to derive formal predictions. Theoretical progress in this area will be governed by the extent to which models of negative priming become more computationally explicit.

### REFERENCES

- BROADBENT, D. E. (1982). Task combination and selective intake of information. *Acta Psychologica*, *50*, 253-290.
- DALRYMPLE-ALFORD, R. C., & BUDAYR, D. (1966). Examination of some aspects of the Stroop color-word test. *Perceptual & Motor Skills*, *23*, 1211-1214.
- DESCHERPER, B., & TREISMAN, A. (1996). Visual memory for novel shapes: Implicit coding without attention. *Journal of Experimental Psychology: Learning, Memory, & Cognition*, *22*, 27-47.
- ERIKSEN, C. W., & ST. JAMES, J. D. (1986). Visual attention within and



- around the field of focal attention: A zoom lens model. *Perception & Psychophysics*, **40**, 225-240.
- FEUSTEL, T. C., SHIFFRIN, R. M., & SALASOO, A. (1983). Episodic and lexical contributions to the repetition effect in word identification. *Journal of Experimental Psychology: General*, **112**, 309-346.
- FOX, E. (1995). Negative priming from ignored distractors in visual selection: A review. *Psychonomic Bulletin & Review*, **2**, 145-173.
- HAWLEY, K. J., & JOHNSTON, W. A. (1991). Long-term perceptual memory for briefly exposed words as a function of awareness and attention. *Journal of Experimental Psychology: Human Perception & Performance*, **17**, 807-815.
- HOUGHTON, G., & TIPPER, S. P. (1994). A model of inhibitory mechanisms in selective attention. In D. Dagenbach & T. H. Carr (Eds.), *Inhibitory processes in attention, memory, and language* (pp. 53-112). San Diego: Academic Press.
- HOUGHTON, G., TIPPER, S. P., WEAVER, B., & SHORE, D. I. (1996). Inhibition and interference in selective attention: Some tests of a neural network model. *Visual Cognition*, **3**, 119-164.
- ISHIHARA, S. (1993). *Ishihara's test for colour-blindness*. Tokyo: Kanehara.
- KUCERA, H., & FRANCIS, W. N. (1967). *Computational analysis of present-day American English*. Providence, RI: Brown University Press.
- LOGAN, G. D. (1990). Repetition priming and automaticity: Common underlying mechanisms? *Cognitive Psychology*, **22**, 1-35.
- LOWE, D. G. (1979). Strategies, context, and the mechanisms of response inhibition. *Memory & Cognition*, **7**, 382-389.
- MACDONALD, P. A., JOORDENS, S., & SEERGOBIN, K. N. (1999). Negative priming effects that are bigger than a breadbox: Attention to distractors does not eliminate negative priming, it enhances it. *Memory & Cognition*, **27**, 197-207.
- MALLEY, G. B., & STRAYER, D. L. (1995). Effect of stimulus repetition on positive and negative identity priming. *Perception & Psychophysics*, **57**, 657-667.
- MAY, C. P., KANE, M. J., & HASHER, L. (1995). Determinants of negative priming. *Psychological Bulletin*, **118**, 35-54.
- MILLIKEN, B., JOORDENS, S., MERIKLE, P. M., & SEIFFERT, A. E. (1998). Selective attention: A reevaluation of the implications of negative priming. *Psychological Review*, **105**, 203-229.
- NEILL, W. T. (1977). Inhibitory and facilitatory processes in selective attention. *Journal of Experimental Psychology: Human Perception & Performance*, **3**, 444-450.
- NEILL, W. T., LISSNER, L. S., & BECK, J. L. (1990). Negative priming in same-different matching: Further evidence for a central locus of inhibition. *Perception & Psychophysics*, **48**, 398-400.
- NEILL, W. T., & MATHIS, K. M. (1998). Transfer-inappropriate processing: Negative priming and related phenomena. In D. L. Medin (Ed.), *The psychology of learning and motivation: Advances in research and theory* (Vol. 38, pp. 1-44). San Diego: Academic Press.
- NEILL, W. T., & VALDES, L. A. (1992). Persistence and negative priming: Steady state or decay? *Journal of Experimental Psychology: Learning, Memory, & Cognition*, **18**, 565-576.
- NEILL, W. T., VALDES, L. A., & TERRY, K. M. (1995). Selective attention and the inhibitory control of cognition. In F. N. Dempster & C. J. Brainerd (Eds.), *New perspectives on interference and inhibition in cognition* (pp. 207-261). New York: Academic Press.
- NEILL, W. T., VALDES, L. A., TERRY, K. M., & GORFEIN, D. S. (1992). Persistence of negative priming: II. Evidence for episodic trace retrieval. *Journal of Experimental Psychology: Learning, Memory, & Cognition*, **18**, 993-1000.
- PARK, J., & KANWISHER, N. (1994). Negative priming for spatial locations: Identity mismatching, not distractor inhibition. *Journal of Experimental Psychology: Human Perception & Performance*, **20**, 613-623.
- POSNER, M. I. (1980). Orienting of attention. *Quarterly Journal of Experimental Psychology*, **32**, 3-25.
- POSNER, M. I., & DEHAENE, S. (1994). Attentional networks. *Trends in Neurosciences*, **17**, 75-79.
- STRAYER, D. L., & GRISON, S. (1999a). Negative priming is contingent on stimulus repetition. *Journal of Experimental Psychology: Human Perception & Performance*, **25**, 24-38.
- STRAYER, D. L., & GRISON, S. (1999b). *Negative priming is not based upon perceptual inhibition*. Manuscript submitted for publication.
- TIPPER, S. P. (1985). The negative priming effect: Inhibitory priming by ignored objects. *Quarterly Journal of Experimental Psychology: Human Experimental Psychology*, **37A**, 571-590.
- TIPPER, S. P., BREHAUT, J. C., & DRIVER, J. (1990). Selection of moving and static objects for the control of spatially-directed action. *Journal of Experimental Psychology: Human Perception & Performance*, **16**, 492-504.
- TIPPER, S. P., & CRANSTON, M. (1985). Selective attention and priming: Inhibitory and facilitatory effects of ignored primes. *Quarterly Journal of Experimental Psychology*, **37A**, 591-611.
- TIPPER, S. P., & DRIVER, J. (1988). Negative priming between pictures and words in a selective attention task: Evidence for semantic processing of ignored stimuli. *Memory & Cognition*, **16**, 64-70.
- TIPPER, S. P., LORTIE, C., & BAYLIS, G. C. (1992). Selective reaching: Evidence for action-centered attention. *Journal of Experimental Psychology: Human Perception & Performance*, **18**, 891-905.
- TIPPER, S. P., MACQUEEN, G. M., & BREHAUT, J. C. (1988). Negative priming between response modalities: Evidence for the central locus of inhibition in selective attention. *Perception & Psychophysics*, **43**, 45-52.

## NOTES

1. In the model developed by Houghton and Tipper (1994; Houghton et al., 1996), inhibition is applied to object field representations (i.e., representations of grouped percepts). However, more recent work envisions a flexible inhibitory system in which the level of representation associated with inhibition is determined by the task demands (Tipper, personal communication). Indeed, the model has been used to account for inhibition of return and this could be viewed in terms of response inhibition. The implementation of this flexible inhibitory system into the computational model is currently under development.

2. Neill and Mathis (1998) recently developed a "TIP/TAP" model of priming that assumes that performance is governed by both representational activation and episodic retrieval. *Transfer inappropriate processing* (TIP) is assumed to be the result of the episodic retrieval of processing information that is incompatible with current processing requirements. *Transfer appropriate processing* (TAP) is assumed to be due either to the episodic retrieval of processing information that is compatible with the current processing requirements or to the persistent activation of the representations associated with processing of the prime. Further speculation based upon TIP/TAP (Neill, personal communication) suggests that under certain circumstances representational activation may mask effects of episodic retrieval. For example, suppose that the presentation of a novel prime trial results in an increase in representational activation such that, relative to novel control trials, performance is facilitated. If this facilitation is of sufficient magnitude, then it may obscure any effects of episodic retrieval. By contrast, the activation of the internal representations of items from the repeated set are likely to be at asymptotic levels. Under these circumstances, it is unlikely that there will be differences in the activation component of processing on the prime and probe trials and the effects of episodic retrieval will thus be observable. However, at present there is no evidence to suggest that either representational activation or episodic retrieval are operating in novel trials in the manner suggested by Neill (personal communication).