

Negative Priming for Spatial Locations: Identity Mismatching, Not Distractor Inhibition

Jooyong Park and Nancy Kanwisher

Negative priming (NP) is commonly thought to occur because distractor inhibition is necessary for target selection (the distractor inhibition hypothesis). Contrary to this account, the selection of a target in the preceding trial is shown to be neither necessary (Experiment 1) nor sufficient (Experiments 2 and 3) for NP in a target localization task modeled after S. P. Tipper, J. C. Brehaut, and J. Driver (1990). Experiments 4 and 5 provide further evidence against the distractor inhibition hypothesis and support an alternative mismatching account: NP in the spatial selection task apparently results from a change in the symbol bound to a given location (D. Kahneman, A. M. Treisman, & B. J. Gibbs, 1992), rather than a change in the status of that location from distractor to target (S. P. Tipper, J. C. Brehaut, & J. Driver, 1990).

In any given moment, we attend to only a small subset of the perceptual information available to us (e.g., Treisman, 1969; cf. Johnston & Dark, 1986). How is this attentional selection accomplished? Logically, selection could be mediated by enhancing the processing of attended objects, by suppressing the processing of unattended objects, or both. To choose between these possibilities, it is necessary to investigate the effect of attention on the representations of both attended and unattended objects.

Important clues about the fate of unattended objects have come from studies of negative priming (NP; e.g., Allport, Tipper, & Chmiel, 1985; Milliken, Tipper, & Weaver, 1994; Neill, 1977; Tipper, 1985; Tipper, Weaver, & Houghton, in press). In a typical NP experiment, two trials are presented in rapid succession; the first is typically called the "prime," and the second is called the "probe." In each trial the subject must ignore the distractor(s) but respond quickly to the target, which is specified by color, symbol identity, or location. NP is the slowing of response to a probe target when it maps to the same response as the prime distractor.

We investigated a particular form of NP, first demonstrated by Tipper, Brehaut, and Driver (1990). Tipper et al. presented subjects with displays containing four position markers (see Figure 1), with a target symbol (@) over one position marker and a distractor symbol (+) over another. Subjects were asked to quickly press the keyboard button

corresponding to the location of the target. Response times (RTs) to the probe target were slower when it appeared in the same location as the prime distractor (as shown in Figure 1) than when the probe target appeared in a previously unoccupied location.

The standard interpretation of NP is that inhibiting distractors is part of the mechanism by which targets are selected (e.g., Allport et al., 1985; Tipper et al., in press). Thus, the delay in responding to the probe target is thought to result from lingering inhibition of that location left over from processing the prime display. In the terminology of Allport et al., when a target is "selected-for-action," distractors are simultaneously "selected-against." Tipper et al. (1990) illustrate the difficulty of selecting a target among distractors with the example of the pike fish, which preys on sticklebacks. Placed in an aquarium with six sticklebacks, the pike takes six times longer to make its first catch than when faced with only a single prey. The key idea is that the presence of other objects interferes with the ability to plan action toward a single object. What NP suggests is that this problem is solved in part by suppressing the representations of the other objects in the display. Thus, NP appears to provide an important insight about the mechanisms underlying attentional selection.

A great deal of evidence has been rallied in support of this account of NP, which we will call the distractor inhibition hypothesis (e.g., Allport et al., 1985; Tipper et al., 1990; Tipper et al., in press). Nevertheless, several critical questions about the hypothesis have yet to be investigated; we address them here using the spatial selection paradigm of Tipper et al. (1990). Most importantly, the distractor inhibition hypothesis implies that selection of a prime target should be *necessary and sufficient* to cause NP for a probe target.

In Experiment 1, we ask whether selection is necessary for spatial NP by testing a case in which no prime target exists to be selected. In Experiments 2 and 3, we ask whether any selection of a prime target is sufficient to produce spatial NP by testing the case of arbitrary selection

Jooyong Park and Nancy Kanwisher, Department of Psychology, University of California, Los Angeles.

This research was supported by National Institute of Mental Health Grant MH45245 to Nancy Kanwisher. We thank Paul Downing for suggesting the mismatching hypothesis, for programming assistance, and for helpful comments on the article. We also thank John Henderson, Ray Klein, Barbara Spellman, and Steven Tipper for comments on the article, and Jin Woo Kim and Abram Yap for testing subjects.

Correspondence concerning this article should be addressed to Jooyong Park, Department of Psychology, University of California, Los Angeles, California 90024-1563. Electronic mail may be sent to park@psych.ucla.edu.

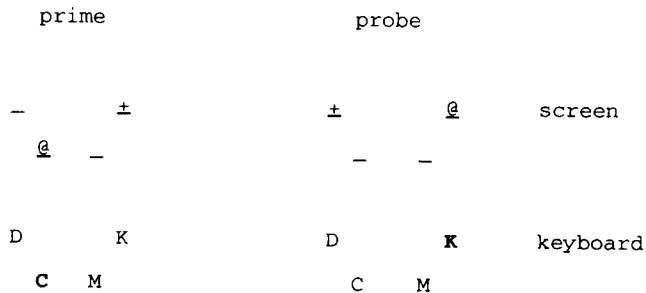


Figure 1. Examples of the prime and probe displays used in Experiment 1A of Tipper, Brehaut, and Driver (1990). The index and middle fingers of each hand were positioned over the keyboard keys D, C, M and K, mirroring the spatial configuration of the perceptual display. The target in each display was an “at” symbol; the distractor was a plus sign. Subjects were asked to quickly press the key corresponding to the location of the “at” symbol in each display. Boldface letters indicate the correct key response for each display.

of a single target from multiple possible targets. In Experiment 4, we directly pit the distractor inhibition hypothesis against an alternative account of the spatial NP; Experiment 5 provides converging evidence for the alternative account.

Experiment 1

Does NP arise whenever distractor items are present, or only when a target item is selected from among those distractors? This experiment was modeled after Experiment 1A of Tipper et al. (1990), but we included additional trials in which the prime displays contained two distractors but no target. Subjects were instructed to make no response to these target-absent primes. If positive selection for a prime target is a necessary condition for NP, then the effect should not result from target-absent primes. On the other hand, if NP results whenever items are “selected-against,” whether or not any item is “selected-for,” then the effect should occur for the target-absent primes.

Method

Subjects. Seventeen subjects participated in this experiment. All subjects were members of the University of California at Los Angeles community; they were under 30 years of age and had normal or corrected-to-normal vision. Subjects received course credit for their participation.

Apparatus. This and all the subsequent experiments described in this article were carried out on a Macintosh IIfx microcomputer with an AppleColor High Resolution RGB monitor. The software used for creating and running the experiments was MacProbe version 1.4 written by Steven Hunt (1993). The experiments were conducted in a room lit only with a 40-watt lamp directed toward the wall to minimize screen reflections.

Materials. Four positions were marked by white rectangular bars near the center of the computer monitor. They were displayed in two rows, as shown in Figure 1. From typical viewing distances, the approximate horizontal visual angle was 8.9° between the two upper outside positions and 4.3° between the two lower inside

positions. The vertical component of the visual angle between the upper outside and lower inside positions was approximately 1.3°. The stimuli were presented above the position markers. The target was an *o*, the distractor was an *x*, and the masks were asterisks. These symbols subtended about .6° × .6°. The stimuli and the procedure were the same as Experiment 1A of Tipper et al. (1990) except that (a) they used “@” as a target and “+” as a distractor whereas we used *o* and *x*, (b) they used small pieces of white tape to mark the four possible loci for stimulus items whereas we used computer-generated rectangles, and (c) they masked only locations where stimulus items were presented whereas we masked all four locations.

Procedure. An instruction sheet was given to the subject first; it was subsequently clarified by the experimenter. Each trial consisted of two displays, the prime and probe. The task was to press the key corresponding to the target (i.e., *o*) position for the prime and then to do the same for the probe. To initiate a trial the subject pressed the space bar, and four position markers appeared that remained on the screen throughout the entire trial. After 1,500 ms a prime display appeared for 150 ms. Then all four positions above the markers were masked by asterisks for 100 ms. The probe display appeared 350 ms after the subject made a response to the prime target. When the subject did not have to make a response to the prime display (see Table 1 for the target-absent conditions) an 845-ms stimulus onset asynchrony (SOA) occurred between the prime and probe displays. This SOA was intended to roughly match the SOA for the target-present conditions.¹ The probe display appeared for 150 ms with a 100-ms postmask, consisting of an asterisk above each position marker. The position markers remained on the screen for another 500 ms before the screen blanked. After the subject responded to the probe display, feedback was given regarding RT and accuracy for the prime and probe.

Each of four keys (D, C, M, and K) was assigned to a corresponding spatial location on the screen as shown in Figure 1. Subjects used the index and middle fingers of each hand to make responses on the keyboard. Thus, if a target was presented on the far right, subjects were to respond by pressing the far right key (K) with the right middle finger. Speed and accuracy of response were both emphasized. Subjects were instructed not to press any key when there was no target in the prime.

After 24 practice trials were completed, subjects received summary feedback of accuracy and mean RTs. The main experiment consisted of 6 blocks of 48 trials. In addition to the feedback provided after each trial (both RT and accuracy), the percentage correct and mean RT for each block were given at the end of the block. The whole experiment lasted about 40 min. At the end of the experiment, subjects were told the purpose of the research.

Design. Experiment 1 used a single-factor within-subjects design with six levels. The levels were a function of the relationship between items in the prime and the probe as shown in Table 1. For the target-present primes, there were three different conditions: control, match, and mismatch. In the target-present control condition, the probe target appeared in one of the two positions that were not occupied in the prime display. In the target-present match condition, the probe target appeared in the same location as the prime target. In the target-present mismatch condition, the probe target appeared in the same location as the prime distractor. The probe distractor was always presented in one of the two locations

¹ Although the target-present SOAs in this experiment in fact average about 600 ms, a subsequent study that matched both target-present and target-absent SOAs at about 600 ms produced the same results.

that were unoccupied in the prime display. These three conditions were included in order to replicate Tipper et al. (1990) and also to insure that subjects attended to the prime displays for the target-absent conditions.

For the target-absent primes, there were three different conditions: nothing, control, and mismatch. In the target-absent nothing trials, none of the four locations was occupied in the prime. In the target-absent control condition, two *x*s were displayed in the prime, and the probe target appeared in a previously unoccupied position. The target-absent mismatch trials also had two *x*s in the prime, but the probe target appeared in the same location as one of them. NP from the target-absent prime was measured by the difference between the target-absent control and the target-absent mismatch conditions, which are analogous to the target-present control and the target-present mismatch conditions. For each condition, there were 48 trials. All six experimental conditions were presented in a random order within each block.

Results and Discussion

One subject was excluded because her overall accuracy across all conditions was less than 70%. For the remaining 16 subjects, the analysis of RTs included only correct responses, and the analysis of probe RTs and errors included only trials in which the prime was responded to correctly. Means of median RTs and percentage of errors for each condition are given in Table 1. Analyses of variance (ANOVAs) were conducted on mean RTs and error rates.² For the target-present primes, the three conditions were not different from one another for either RTs or error rates, both F s < 1, *ns*.

Analysis of the probe target responses showed that RTs for the target-absent conditions were significantly slower than those for the target-present conditions, $F(1, 15) = 8.9$, $p < .005$, $MS_e = 138$. Error rates for the target-present conditions were not significantly different from those for the target-absent conditions, $F(1, 15) = 2.3$, $p > .10$, $MS_e = 6.3$. The slower RTs in target-absent conditions may be caused by residual inhibition from withholding a response to the prime.

Supplementary planned comparisons were conducted for the probe RTs. The target-present conditions replicate the NP effect observed by Tipper et al. (1990): Average RT in the target-present mismatch condition was significantly slower than that in the target-present control condition, $t(15) = 2.7$, $p < .02$, $MS_e = 14.2$ (75% of the subjects showed NP). Error rate for the mismatch condition was also significantly higher than that for the control condition, $t(15) = 2.2$, $MS_e = 2.7$, $p < .05$. RTs for the target-present match condition were not significantly faster than the target-present control condition, $t(15) = 1.4$, $p > .10$, $MS_e = 27.5$. However, error rates for the match condition were significantly lower than the control condition, $t(15) = 3.0$, $p < .01$, $MS_e = 1.8$.

Analyses for the target-absent conditions showed that RTs in the mismatch condition were significantly slower than RTs in the control condition, $t(15) = 3.9$, $p < .005$, $MS_e = 15.7$. That is, NP occurred even when there was no

target in the prime.³ There was no difference in RTs for the nothing and the control conditions, $t < 1$, *ns*. Error rates were not different from the control condition: For the mismatch condition, $t(15) = 1.7$, $p > .10$, $MS_e = 1.6$; for the nothing condition, $t(15) < 1$, *ns*.

A comparison of the two control conditions (target-absent and target-present) did not reach significance: for RTs, $t(15) = 1.4$, $p > .10$, $MS_e = 27.9$, and for error rates, $t(15) < 1$, $p > .40$.

For the target-absent prime trials, subjects did not select a target, yet NP was still observed. Apparently, selection for a prime target is not a necessary condition for NP. This result implies that either (a) distractor inhibition results from selection against distractors, independent of whether any positive selection occurs for a target, or (b) some other process mediates NP.

Experiment 2

In Experiment 1 we showed that selection for a prime target is not a necessary condition for NP. In Experiment 2 we asked whether the selection of a prime target is sufficient for NP. To answer this question, trials were run in which the primes contained two identical targets, and subjects were asked to respond to either one of them. This situation is analogous to that of the pike and sticklebacks described in the introduction. If selection for a prime target is sufficient for NP, then the unselected alternative of the two prime targets should cause NP for a probe target appearing in the same location.

Method

Subjects. Eighteen subjects from the previously described subject pool participated in this experiment. None had participated in Experiment 1.

Materials and procedure. Materials were almost identical to those in Experiment 1, except that double-target displays were substituted for the target-absent prime displays. The double-target prime displays were made by changing the distractor (*x*) in the target-present prime into a target (*o*). The task was again to press the key corresponding to the target (i.e., *o*) position in both the prime and probe. Thus, subjects had to make a selection between the two possible targets in the prime. That is, they had to press either of the two keys corresponding to the *o* locations. There were 24 practice trials and 288 experimental trials, and the experiment lasted about 40 min. In all other respects, this experiment was identical to Experiment 1.

² Although Tipper and his colleagues used a nonparametric Wilcoxon test, we report ANOVA because it allows a test of both main effects and interactions. However, we also carried out Wilcoxon tests where possible, which produced the same pattern of results.

³ Tipper, Eissenberg, and Weaver (1992) reported a similar finding of inhibition when the probe target appeared in the location of the distractor in a one-distractor-only prime. They took this effect (which they called "response inhibition") to be different from negative priming. However, their data are perfectly consistent with the mismatching hypothesis we propose in Experiment 4.

Table 1
 Design and Results of Experiment 1 as a Function of the Relationship Between the Prime Distractor and the Probe Target

Stimulus/ measure	Target present			Target absent		
	Control	Match	Mismatch	Nothing	Control	Mismatch
	Design					
Prime	<u>x</u> . . o	<u>x</u> . o .	o . <u>x</u>	<u>x</u> . . <u>x</u>	. <u>x</u> . <u>x</u>
Probe	. <u>x</u> o .	. <u>x</u> o .	. <u>x</u> o .	. <u>x</u> o .	. <u>x</u> o .	. o <u>x</u> .
	Results					
Prime						
RT (ms)	300	296	291	—	—	—
% Errors	2.7	2.7	2.7	1.0	1.8	1.4
Probe						
RT (ms)	412	397	425	429	425	447
% Errors	2.3	0.4	4.4	1.0	2.0	1.7

Note. The four underlines represent the four successive locations in each display (which were actually displayed in two rows as shown in Figure 1, not one); periods indicate display locations containing neither targets nor distractors. Distractors are represented by “x.” Correct targets are shown as boldface circles. RT = response time.

Design. Experiment 2 used a two-factor within-subjects design. The first factor was prime type, single-target versus double-target. The single-target conditions constitute another replication of Tipper et al. (1990). The double-target conditions were made by changing the distractor (x) in the single-target prime into a target (o). In the double-target conditions, subjects could respond to either one of the two targets in the prime, so the probe target location was selected contingent upon the prime response. For the single-target condition, the levels were: control, match, and mismatch. For the double-target conditions, they were control, selected-match, and unselected-match. For the selected-match trials, the probe target location was the same as the prime target location. For the unselected-match trials, the probe target location was the same as the unselected target in the prime. Thus, according to the distractor inhibition hypothesis, the single-target match condition is analogous to the double-target selected-match condition, and the single-target mismatch condition is analogous to the double-target

unselected-match condition. Each of these pairs of conditions was treated as one level of the probe type factor for the purpose of the ANOVA.

Results and Discussion

Two subjects were excluded because their overall accuracy across all conditions was less than 70%. For the remaining 16 subjects, means of median RTs and associated errors for all conditions were calculated in the same way as in Experiment 1, and they are given in Table 2. A repeated measures ANOVA for the prime target RTs revealed no main effect of the single versus double target, no main effect of probe type, and no interaction between the two, all *F*s < 1.5, *p*s > .25. Subjects made more errors for the primes in

Table 2
 Design and Results of Experiment 2 as a Function of the Relationship Between the Prime Distractor and the Probe Target

Stimulus/ measure	Single-target			Double-target		
	Control	Match	Mismatch	Control	Selected-match	Unselected-match
	Design					
Prime	<u>x</u> . . o	<u>x</u> . . o	<u>x</u> . . o	o . o .	o . o .	o . o .
Probe	. o <u>x</u> .	. . <u>x</u> o	o . <u>x</u> .	. o . <u>x</u>	o . . <u>x</u>	. <u>x</u> o .
	Results					
Prime						
RT (ms)	397	395	399	395	396	396
% Errors	3.5	1.8	3.0	1.0	1.0	1.0
Probe						
RT (ms)	386	376	418	409	371	378
% Errors	1.2	1.1	4.0	3.2	0.9	1.7

Note. The four underlines represent the four successive locations in each display (which were actually displayed in two rows as shown in Figure 1, not one); periods indicate display locations containing neither targets nor distractors. Distractors are represented by “x.” Selected targets are shown as boldface. RT = response time.

the single-target condition than the double-target condition, $F(1, 15) = 11, p < .005, MS_e = 2.2$.

A 2×3 repeated measures ANOVA, with variables of prime type (single-target vs. double-target) and probe type was performed for the probe target RTs. The analysis revealed a main effect of prime type, $F(1, 15) = 10.5, p < .01, MS_e = 126$, a main effect of probe type, $F(2, 30) = 10, p < .001, MS_e = 628$, and a significant Prime Type \times Probe Type interaction, $F(2, 30) = 38, p < .001, MS_e = 206$. The origin of the interaction was revealed from further analyses for each prime type as follows. The single-target conditions replicated the findings of Tipper et al. (1990): A significant difference was found between the control and mismatch conditions (i.e., NP was found), $t(15) = 9.2, p < .001, MS_e = 9.8$ (all the subjects showed NP), but no facilitation was found for the selected-match condition compared to the control condition, $t(15) = 1.4, p > .2, MS_e = 20.9$. Because significantly more errors were observed for the mismatch condition than the control condition, $t(15) = 3.1, p < .01, MS_e = 2.5$, this result cannot be accounted for by a speed-accuracy trade-off.

The analogous comparisons among the double-target conditions, however, revealed that RTs for both the selected-match and unselected-match conditions were significantly faster than the control condition, $t(15) = 5.2, p < .001, MS_e = 20.7$, and $t(15) = 3.9, p < .005, MS_e = 21.9$, respectively. Error rates showed the same pattern, being greater for the control condition than the other two conditions, $t(15) = 2.8, p < .05, MS_e = 2.3$, for the selected-match, and $t(15) = 2.4, p < .05, MS_e = 1.8$, for the unselected-match. Finally, the selected-match and unselected-match conditions were not significantly different in RTs, $t(15) = 1.1, p > .25, MS_e = 18.8$, or in errors, $t(15) < 1, ns$.

In this experiment, an act of selection was required when the prime contained two targets, yet the unselected target did not produce NP. Notice that selection appears to have been just as efficient in the double-target conditions as in the single-target conditions, as evidenced by similar prime RTs in these two conditions. A very similar experiment, with similar results, was reported by Neill, Valdes, and Terry (1992). Apparently, "selecting-for" a target is not sufficient to produce NP from unselected items.

Experiment 3

The lack of NP from the unselected prime target in Experiment 2 is open to an alternative interpretation, however. Perhaps subjects did not have to make a selection at all in the double-target condition. Instead, because all locations containing symbols were legal targets in this condition, subjects could have simply responded to any location that reached some internal threshold first.⁴ This "horse-race" account is implausible because the double-target trials (where this strategy might have been effective) were mixed in with trials containing distractor *x*s where the strategy would have produced incorrect responses. Nevertheless, it is remotely possible that subjects might have been able to apply the horse-race strategy on the fly on only double-

target trials, perhaps after a preliminary check determined that all the symbols in the display were identical. To test this possibility, a distractor *x* was added to the two alternative prime targets in Experiment 3. Because each trial contained a distractor, subjects could no longer simply respond to the symbol-containing location that they became aware of first. Instead, some attention to symbol identities and some selection for targets or against distractors would be necessary.

Another goal for Experiment 3 was to equalize all the contingencies between particular prime and probe displays. In Experiments 1 and 2, the prime display conveyed information about where items would be likely to appear in the probe display.⁵ For example, (a) whenever any probe item occurred in a location that was occupied in the prime (by a target or a distractor), then that item was a target; (b) locations that were empty in the prime were more likely to contain distractors (.5) than targets (about .16) in the probe; and (c) probe targets were more likely to appear in the location of the prime distractor (.33) than in a location that was empty in the prime (.16). If subjects were sensitive to these contingencies between the prime and probe displays in Experiments 1 and 2, their RTs could have been affected. In Experiment 3 all prime-target contingencies were removed: Items in the prime displays afforded no information about the location of targets and distractors in the probe.

Method

Subjects. Sixteen subjects from the previously described subject pool participated in this experiment. None had been tested in Experiments 1 and 2.

Materials and procedure. Materials were adapted from those in Experiment 2 with the following modifications. Prime displays always contained two targets (*o*s) and a distractor (*x*). The task was again to press the key corresponding to the target (i.e., *o*) position for both the prime and probe. Subjects were asked to make a selection between the two possible targets in the prime, ignoring the distractor, that is, they had to press either of the two keys corresponding to the *o* locations. Probe displays always contained one target (*o*) and one distractor (*x*). There were 32 practice trials and 192 experimental trials.

Design. In Experiment 3 we used a single-factor within-subjects design with four levels. The levels were a function of the relationship between items in the prime and the probe: control, selected-match, unselected-match, and mismatch. In the control condition, the probe target appeared in a position that was not occupied in the prime display. In the selected-match and unselected-match conditions, the probe target appeared in the location of the selected or unselected prime target, respectively. In the mismatch condition, the probe target appeared in the same location as the prime distractor. The probe distractor was presented equally often across the remaining three locations after the target location was set by the condition of that trial. Thus, the prime display provided no information about target and distractor locations in the probe.

⁴ We thank John Henderson and Jon Driver for pointing this out.

⁵ We thank Ray Klein for pointing this out.

Results and Discussion

Two subjects were excluded because their overall accuracy across all conditions was less than 70%. For the remaining 14 subjects, means of median RTs and associated errors for all conditions were calculated in the same way as in Experiment 1, and they are given in Table 3. A repeated measures ANOVA revealed no significant difference in the prime target RTs, $F(3, 39) = 2.8, p > .05, MS_e = 123.7$, or in errors, $F(3, 39) = 1.9, p > .10, MS_e = 1$.

The NP effect, which is the slowing of RT in the mismatch condition compared to the control condition, was significant, $t(13) = 2.3, p < .05, MS_e = 20.8$ (83% of subjects showed NP). There were also significantly greater error rates in the mismatch condition than in the control condition, $t(13) = 2.5, p < .05, MS_e = 1.8$. Significant facilitation (compared with the control condition) was observed in both match conditions regardless of selection: for the selected-match condition, $t(13) = 3.8, p < .005, MS_e = 14.9$; for the unselected-match condition, $t(13) = 3.1, p < .01, MS_e = 19.3$. The two match conditions were not different from each other, $t(13) < 1, ns$. Error rates for the different probe conditions were not significantly different, $F(3, 39) = 2, p > .10, MS_e = 3.6$.

Because all trials contained a distractor x , subjects in this experiment could not use the horse-race strategy of simply ignoring identity information and responding to any location containing a symbol. Instead, subjects had to attend to symbol identity and make some selection between targets and distractors on every trial in order to respond correctly. Nevertheless, although some selection must have occurred in this experiment, the unselected alternative target in the prime produced no NP in the probe.

Table 3
Design and Results of Experiment 3 as a Function of the Relationship Between the Prime Distractor and the Probe Target

Stimulus/ measure	Condition			
	Control	Mis- match	Selected- match	Unselected- match
	Design			
Prime	<u>x</u> <u>.</u> <u>o</u> <u>o</u>	<u>x</u> <u>.</u> <u>o</u> <u>o</u>	<u>x</u> <u>.</u> o <u>o</u>	<u>x</u> <u>.</u> <u>o</u> <u>o</u>
Probe	<u>.</u> <u>o</u> <u>x</u> <u>.</u>	<u>o</u> <u>x</u> <u>.</u> <u>.</u>	<u>x</u> <u>.</u> <u>o</u> <u>.</u>	<u>.</u> <u>.</u> <u>x</u> <u>o</u>
	Results			
Prime				
RT (ms)	418	416	419	408
% Errors	3.1	3.5	1.8	2.3
Probe				
RT (ms)	424	442	403	401
% Errors	4.7	7.2	3.9	5.2

Note. The four underlines represent the four successive locations in each display (which were actually displayed in two rows as shown in Figure 1, not one); periods indicate display locations containing neither targets nor distractors. Distractors are represented by "x." Selected targets are shown as boldface. RT = response time.

On the other hand, it remains possible that a modified version of the horse-race strategy was used in Experiment 3. Namely, subjects might have inhibited the distractor x location but then responded to whichever of the alternative targets reached awareness first. On this account, only the distractor x , not the unselected alternative target, was "selected-against." This account, which is consistent with the distractor inhibition hypothesis, will be tested in Experiment 4.

Discussion of Experiments 1–3

In Experiments 1–3, we examined the logical relationship between selection for a prime target and the spatial NP effect. These experiments showed that selection for a prime target is neither necessary nor sufficient for obtaining NP in a subsequent probe target localization task. In Experiment 1, NP resulted whenever distractors were "selected-against," regardless of whether a target was "selected-for." In Experiments 2 and 3, one of two identical alternative targets was selected, but its unselected partner produced no NP. These results place considerable strain on the original distractor inhibition hypothesis, which argues that NP from prime distractors is a direct result of selecting for a prime target. A modified distractor inhibition hypothesis could explain the results of Experiments 1–3, however, if (a) distractors are always selected against, whether or not a target is selected for in the same display, and (b) selection for one of several possible targets (e.g., Tipper et al.'s, 1990, stickleback example) need not entail inhibition of the unselected alternative targets.

Next, we consider an alternative account of the spatial NP effect, which we call the mismatching hypothesis. A variant of this idea was first proposed by Allport et al. (1985) to account for NP in the task of naming colored letters. In the present context, the mismatching hypothesis holds that responses are slowed when the probe target differs from the item that occupied its position in the prime display, independent of whether that prime item was a distractor or a target. Conversely, a benefit may occur when the probe target is the same symbol as the item that appeared in that location in the prime display (see also Kahneman, Treisman, & Gibbs, 1992).

Both the mismatching and the distractor inhibition hypotheses account for the standard NP effects observed by Tipper et al. (1990), but they do so in different ways. According to the mismatching hypothesis, NP is caused by the change in the bindings of symbol identities⁶ to locations between the prime and probe, regardless of whether the prime symbol is a target or distractor. According to the distractor inhibition hypothesis, on the other hand, it is the

⁶ It is unclear whether the critical factor is the matching or mismatching of exact shapes, symbol identities abstracted across letter case, or more abstract response categories. However, recent findings by Connelly, Hasher, and Kimble (1992) and Tipper, Weaver, and Houghton (in press) suggest that matching processes depend on the task such that mismatching incurs a cost only for task-relevant attributes.

change in the status of a given location from containing a distractor in the prime to a target in the probe that incurs the cost, irrespective of the change in the symbols occupying that location. It is difficult to choose between these two accounts in standard NP experiments, because changes in symbol identities are perfectly correlated with changes in target-distractor status.

Tipper et al. (1990) considered a possibility that is similar to the mismatching hypothesis just described: that the NP effect observed in their experiments "was produced by a startle reaction to the change in shape" (p. 500) of the probe target. As evidence against this startle hypothesis, they showed that there was no RT cost when each of the prime and probe displays contained one target item without a distractor and the symbol identities were different between the prime and probe (Experiment 4), and when no selection was required for the probe (Experiment 5). However, neither of these experiments required subjects to encode the identity of the probe target item, because distractors never appeared in the probe. Subjects could simply press the button corresponding to the object in the probe display without worrying about its identity. If the mismatching hypothesis applies only to changes in symbol-to-location bindings that must be encoded to perform the task, Tipper et al.'s Experiments 4 and 5 offer no evidence against it.

A more direct comparison of the mismatching and distractor inhibition hypotheses was carried out in our next experiment, by changing the target symbol from an *x* in the prime to an *o* in the probe. With this manipulation, the change in symbol identity and the change in target-distractor status at a given location are perfectly anticorrelated. A similar manipulation was originally introduced in a nonspatial selection task of naming letters of a specified color (e.g., Allport et al., 1985; Tipper & Cranston, 1985). The differences between the spatial and the nonspatial selection tasks will be addressed in the General Discussion section.

Experiment 4

We designed Experiment 4 to enable us to choose between the distractor inhibition and mismatching accounts of NP in the target localization task. The task was to press the button corresponding to the location containing an *x* in the prime, and then to press the button corresponding to the location containing an *o* in the probe.

Recall that it is the change in target-distractor status that causes NP according to the distractor inhibition hypothesis, but the change in the symbol identity that causes NP according to the mismatching hypothesis. Thus, the distractor inhibition and mismatching hypotheses make opposite predictions for the two critical conditions in this experiment. Consider the symbol-mismatch condition, in which the probe target (*o*) appears in the same location as the prime target (*x*). According to the distractor inhibition hypothesis, no NP should be found in this condition, because there is no change in the target-distractor status at the probe target location. However, according to the mismatching hypothesis, NP should be observed in this condition because the

actual symbol occupying that location changes between the prime and probe. In the symbol-match condition, the *os* appear in the same location in the prime and probe. For this condition, the distractor inhibition hypothesis predicts NP because the probe target appears in the same location as the prime distractor. However, the mismatching hypothesis predicts no NP in this condition and possibly even a benefit, because the symbol at that location does not change between the prime and probe.

Method

Subjects. Eighteen subjects from the previously described subject pool participated in this experiment. All were unfamiliar with the purpose of the study.

Materials and procedure. Materials were identical to the target-present conditions in Experiment 1. The task was to press the key corresponding to the target position. The target in the prime was an *x* and the target in the probe was an *o*. There were 36 practice trials, and the experiment lasted about 25 min. In all other respects, this experiment was identical to Experiment 1.

Design. Experiment 4 used a single-factor within-subjects design. The probe type had three levels: control, symbol-mismatch, and symbol-match.

Results and Discussion

Two subjects were excluded because their overall accuracy was less than 70%. For the remaining 16 subjects, means of median RTs and associated errors for all conditions were calculated in the same way as in Experiment 1, and they are given in Table 4. For the prime display, a repeated measures ANOVA showed no difference in RTs or

Table 4
Design and Results of Experiment 4 as a Function of Whether the Probe Target Was the Same as the Letter Occupying That Position in Prime ("Symbol-Match") or Not ("Symbol-Mismatch")

Stimulus/ measure	Condition		
	Control	Symbol-mismatch	Symbol-match
	Design		
Prime	. x . <u>o</u>	. x . <u>o</u>	. x . <u>o</u>
Probe	<u>x</u> . o .	. o <u>x</u> .	<u>x</u> . . o
	Results		
Prime			
RT (ms)	511	512	505
% Errors	5.5	6.1	5.1
Probe			
RT (ms)	513	578	468
% Errors	3.5	8.7	1.3

Note. The four underlines represent the successive locations in each display (which were actually displayed in two rows as shown in Figure 1, not one); periods indicate display locations containing neither targets nor distractors. Distractors are represented by "x." The task was to press the button corresponding to the location of "x" in the prime and then "o" in the probe. Correct targets are shown as boldface circles. RT = response time.

errors rates between the three different types of prime, both $F_s < 1$, *ns*.

For the probe displays, RTs in the symbol-mismatch condition were significantly slower than the control condition, $t(15) = 6.4$, $p < .001$, $MS_e = 30$ (94% of the subjects showed this pattern). However, the symbol-match condition was significantly faster than the control condition, $t(15) = 4.8$, $p < .001$, $MS_e = 25.6$ (94% of the subjects showed this pattern). The main effect of conditions on error rates was also significant, $F(2, 30) = 11.2$, $p < .001$, $MS_e = 20.7$. A simple comparison with the control condition revealed a significantly lower error rate for the match condition, $t(15) = 2.6$, $p < .02$, $MS_e = 2.4$, but a significantly higher error rate for the mismatch condition, $t(15) = 2.9$, $p < .01$, $MS_e = 5.0$.

These results exactly fit the predictions from the mismatching hypothesis: A delay occurred when the symbols occupying the probe target location changed between the prime and probe, but facilitation was found when the symbols at that location did not change. These results are inconsistent with the distractor inhibition hypothesis.

Experiment 5

Thus far, we have shown that NP does not result from the selection of prime targets, but instead from the cost of changing the symbol bound to a given location or object (Experiments 1–4). A similar set of findings was reported by Kahneman et al. (1992) under conditions in which no task was associated with the prime display.

Kahneman et al. (1992) presented subjects with displays in which 8 empty boxes appeared on the screen. Then two, four, or eight different letters appeared briefly, each inside its own box. After the letters disappeared the empty boxes remained on the screen for a brief interval. Finally, a single letter appeared inside one of the boxes, which the subject had to name as quickly as possible. The finding of interest was that if the target letter had been previously flashed inside the same box, RTs were lower than if the letter had been previously flashed inside a different box. Kahneman et al. call this the object-specific preview effect and argue for a perceptual representation in which letter identities are bound to particular objects, such that priming is greatest when a letter reappears within the same object.

If the NP observed in the present experiments is related to (or the same as) the effect reported by Kahneman et al. (1992), then it should obtain even if subjects have no task at all to perform on the prime display. In Experiment 5 we tested this prediction by presenting stimuli just like those used in the target-present conditions in Experiment 1, but we asked subjects to respond only to the probe, not the prime. In Experiment 5 we also investigated the time course of the development of the effect by varying the interstimulus interval (ISI) between the prime and probe stimuli (cf. Neill & Valdes, 1992; Neill, Valdes, Terry, & Gorfein, 1992; Tipper, Weaver, Cameron, & Brehaut, 1991).

Method

Subjects. Thirty subjects from the previously described subject pool participated in this experiment. All were unfamiliar with the purpose of the study.

Materials and procedure. Materials were the same as the target-present conditions from Experiment 1, crossed with two different ISIs. The prime display was presented for 150 ms, followed by a mask for 100 ms. After a variable interval of 70 ms or 300 ms with only position markers (producing ISIs of 175 and 400, respectively), the probe display was presented for 150 ms, followed by a mask for 100 ms. The task was to press the key corresponding to the target (o) position for the probe display, ignoring the prime display. There were 48 practice trials and 288 experimental trials, and the experiment lasted about 35 min. In all other respects, this experiment was identical to Experiment 1.

Design. We used a two-factor within-subjects design. The first factor was the ISI between the prime and probe, 175 ms versus 400 ms. The second factor was probe type: control, mismatch, and match, as in the target-present conditions of Experiment 1.

Results and Discussion

Four subjects were excluded because their overall accuracy was less than 70%. For the remaining 26 subjects, the correct responses for the probe were analyzed. The response intrusion rate for the prime was less than 1%. Means of median RTs and associated errors for all probe conditions are given in Table 5.

A 2×3 repeated measures ANOVA, with variables of ISI (175 ms and 400 ms) and probe type (control, match and mismatch), was performed for the probe target RTs. The analysis revealed a main effect of ISI, $F(1, 25) = 134$, $p < .001$, $MS_e = 473$, a main effect of probe type, $F(2, 50) = 12.4$, $p < .001$, $MS_e = 800$, and a significant ISI \times Probe Type interaction, $F(2, 50) = 7.1$, $p < .005$, $MS_e = 299$. Analysis of errors showed a main effect of ISI, $F(1, 25) = 6.5$, $p < .05$, $MS_e = 6.8$, a main effect of probe type, $F(2,$

Table 5
Design and Results of Experiment 5 as a Function of Interstimulus Interval and the Relationship Between the Prime Distractor and the Probe Target

Stim/ meas	Interstimulus interval					
	175 ms			400 ms		
	Control	Match	Mmtch	Control	Match	Mmtch
	Design					
Prime	<u>x . . o</u>	<u>x . . o</u>	<u>x . . o</u>	<u>x . . o</u>	<u>x . . o</u>	<u>x . . o</u>
Probe	<u>. o . x</u>	<u>. . x o</u>	<u>o . x .</u>	<u>x . . x o</u>	<u>. . x o</u>	<u>o . x .</u>
	Probe results					
RT (ms)	508	500	515	470	446	487
% Error	6.3	4.6	11.3	5.2	3.0	7.4

Note. The four underlines represent the successive locations in each display (which were actually displayed in two rows as shown in Figure 1, not one); periods indicate display locations containing neither targets nor distractors. Distractors are represented by "x." Correct targets are shown as boldface circles. RT = response time; Stim/meas = stimulus/measure; Mmtch = mismatch.

50) = 26, $p < .001$, $MS_e = 3.6$; the interaction of the two did not reach significance, $F(2, 50) = 2.6$, $p > .08$, $MS_e = 2.6$.

For each level of ISI, both the facilitation from a match and delay from a mismatch were tested against the control condition. Neither effect was significant for the ISI of 175 ms, $t_s < 1$, *ns*. However, at the 175-ms ISI, the error rate for the symbol-mismatch condition was significantly greater than for the control condition, $t(25) = 4.6$, $p < .001$, $MS_e = 1.9$. For the 400-ms ISI conditions, a significant facilitation was found for the symbol-match condition, $t(25) = 4.4$, $p < .001$, $MS_e = 20.3$, and a significant delay for the symbol-mismatch condition, $t(25) = 3.4$, $p < .005$, $MS_e = 16.8$. Errors at the 400-ms ISI showed a similar pattern: The error rate was lower for the symbol-match condition than the control condition, $t(25) = 2.9$, $p < .01$, $MS_e = 1.3$, but higher for the symbol-mismatch condition than for the control condition, $t(25) = 2.1$, $p < .05$, $MS_e = 1.8$.

These results show that even when there was no task at all associated with the prime display, facilitation was observed for the match condition, and a delay was observed for the mismatch condition. Thus, the NP observed in this task is apparently better accounted for by the object-file reviewing process described by Kahneman et al. (1992) than by the distractor inhibition account of Tipper and his colleagues (e.g., Tipper et al. 1990; Tipper et al., in press).

The RT data from this experiment also appear to demonstrate that mismatching delays and matching benefits take time to develop: Neither effect was significant in the RT data for the ISI of 175 ms (SOA = 325 ms), but both effects were significant when the ISI was increased to 400 ms (SOA = 550 ms). However, there are two reasons to be cautious about this conclusion. First, a significant mismatching effect occurred in the error data for the short ISI. Second, Kahneman et al. (1992) found significant object-specific priming effects at SOAs of less than 250 ms in their Experiments 3 and 4. A better understanding of the time course of the development of matching and mismatching effects will have to await future research.

General Discussion

The NP paradigm has been widely used to study the mechanisms of attentional selection. The slower response to a target when it is identical (or related) to a previously ignored item has been taken as evidence that target selection is accomplished in part by inhibition of distractors (Tipper et al., 1990; Tipper et al., in press). In the present experiments, we asked whether selection of a prime target is in fact the cause of NP for locations as reported by Tipper et al. (1990).

In Experiment 1, NP occurred in the absence of a target in the prime, implying that selection for a prime target cannot be a necessary condition for NP. In Experiments 2 and 3, subjects arbitrarily selected one of two candidate targets. The unselected target caused facilitation, not NP, showing that selection of a prime target is not sufficient for NP in the target localization task. These results suggest that selection for a target has little to do with NP in the spatial selection task used by Tipper et al. (1990).

According to our alternative mismatching hypothesis, spatial NP is caused by a change in the bindings of symbol identities to locations (or objects) between the prime and probe. Experiment 4 pitted the mismatching and distractor inhibition hypotheses against each other by changing target identities between the prime (x) and the probe (o). The data were consistent with the mismatching but not the distractor inhibition hypothesis: (a) Facilitation occurred when the probe target was the same symbol that appeared in that location in the prime, despite its change in status from distractor to target, and (b) inhibition occurred when the probe target was a different symbol from the one that appeared in that location in the prime even though both items were targets. Finally, Experiment 5 showed facilitation from a match and delay from a mismatch between the prime and probe, even when there was no task associated with the prime display at all. In summary, the symbol-mismatching hypothesis succeeds at explaining the present results and other related findings where the distractor inhibition hypothesis fails.

Spatial NP Effects and Object-Specific Reviewing

The results of Experiment 5 suggest that the mismatching effect and the object-specific preview effect reported by Kahneman et al. (1992) are mediated by the same underlying mechanism in which visual attributes are bound to locations (or objects). In fact, Kahneman et al. noted the similarity between their results and those of Tipper et al. (1990) and commented that the two phenomena are "complementary," given that NP is mediated by inhibition but the object-specific preview effect is mediated by excitation from the first display. However, this observation does not seem quite right in light of the present results, because both phenomena can be explained in terms of the match or mismatch in the identity-to-location bindings between prime and probe. In the NP effect, a delay was observed because of the mismatch in the bindings; in the object-specific preview effect, facilitation is observed because the bindings match.

One possible problem for the mismatching hypothesis is the lack of facilitation observed when bindings were not changed between prime and probe in some NP studies (e.g., the match conditions in Experiments 1 and 2). In addition to the present Experiments 1 and 2, three other studies using the same spatial NP paradigm contained a match condition (Neill, Valdes, & Terry, 1992; Shapiro & Loughlin, 1993; Tipper et al., 1990). Of these studies, only Neill, Valdes, and Terry obtained a facilitation effect for the match condition, compared to the control condition in which the probe target occupied a position that was empty in the prime. Both in Tipper et al. (1990) and in Experiments 1 and 2 of our study, no facilitation was observed, and in Shapiro and Loughlin even a significant delay was observed.

Thus, although mismatching costs occurred in each experiment (relative to the control condition), matching benefits occurred only in some. Although the exact reason for the latter discrepancy is not clear, the reliance on a baseline

to distinguish costs from benefits is notoriously problematic (Jonides & Mack, 1984). What is consistent across all of the reported experiments using this paradigm is that RTs are faster in the symbol-match condition than in the symbol-mismatch condition. This finding is analogous to the advantage of same-object over different-object conditions observed by Kahneman et al. (1992).

Can the Mismatching Hypothesis Account for Other Spatial NP Effects?

The mismatching hypothesis can explain all of the data in the present study. Can it account for all the NP observed in spatial tasks reported elsewhere? Because the mismatching hypothesis explains NP in terms of a mismatch between the prime distractor and the probe target, it would not be able to account for any cases of NP in which the prime distractor was identical to the probe target. One such case has been reported, which we consider next.

Milliken et al. (1994) used a task in which a colored-letter target could appear in one of four possible positions (left, right, up, and down) with respect to a central cue. The task was to move a joystick in the direction of the target, which was the same color as the central cue (a color patch). The cue was presented either prior to or simultaneous with the stimulus display, and the relationship between the prime distractor and the probe target was manipulated. When the prime distractor was identical (in color, letter identity, and location) to the probe target, Milliken et al. found facilitation for the precue condition but a delay for the simultaneous condition. Although the facilitation effect for the precue condition is consistent with the mismatching hypothesis, the delay for the simultaneous cue condition is not.

Thus, Milliken et al.'s (1994) experiments may provide a genuine case of spatial negative priming that cannot be accounted for by the mismatching hypothesis. However, an alternative account of this finding is that the delay was caused by a mismatching of the entire cue and target group, which may have been perceived as a unit because they were displayed and processed together. Such grouping would only be expected when the cue was simultaneous with the display, not when the cue appeared before the display—consistent with the fact that costs were observed in the simultaneous but not the precue condition. Thus, while results of Milliken et al. may constitute a case of spatial NP that is not due to mismatching, alternative accounts of this finding are possible. Future research will be necessary to determine whether there are any unambiguous cases of NP that cannot be explained by the mismatching hypothesis.

Is All NP Due to Mismatching?

The present results suggest that spatial NP does not result from selection per se, but instead results from a change in the bindings of symbol identities to locations (or objects). However, it remains to be seen whether the NP observed in other nonspatial selection tasks (e.g., Allport et al., 1985; Lowe, 1979; Neill, 1977; Neill, Lissner, & Beck, 1990)

might also be better explained by the mismatching hypothesis. Several findings from other studies suggest caution in extending the present conclusions beyond NP in spatial tasks to NP in letter- or picture-naming tasks.

In the article in which the term “negative priming” was originally coined, Allport et al. (1985) presented subjects with successive pairs of displays, each of which consisted of one green letter superimposed on a red letter. The task was to first report the red letter from the second display (the probe), then the red letter from the first display (the prime). When the red probe target letter was the same as the green prime letter, subjects were slower to respond than if the probe target letter had not occurred in the prime display. This result was explained in terms of inhibition of the prime distractor.

Tipper and Cranston (1985) asked whether the negative priming observed in this task was best explained by distractor inhibition or by a cost in changing the color-to-identity bindings between the prime and probe (analogous to a mismatch). They used the same superimposed red and green letter stimuli just described, but asked subjects to first name the green letter in the probe and then the red letter in prime. They found NP when the green prime distractor matched the green probe target, consistent with the distractor inhibition but not the mismatching hypothesis. Notice that the logic behind this experiment and Experiment 4 in the present article is the same.

Thus, while our Experiment 4 suggests that mismatching and not distractor inhibition underlies NP in the spatial selection task, Tipper and Cranston's (1985) Experiment 4 suggests that distractor inhibition (and not mismatching) underlies NP in their task of naming letter identities on the basis of color. Whether this discrepancy reflects an actual difference in the mechanisms underlying selection in the two tasks, or some other difference between the two paradigms is a question for future research.⁷

Conclusions

NP in the spatial selection task of Tipper et al. (1990) does not seem to occur because the selection of spatial targets necessarily entails inhibition of distractors. Instead, the present results suggest that spatial NP reflects the cost of changing the identity of the symbol bound to a given location. Although some evidence suggests that this mismatching account may not be the correct explanation for the NP observed in other nonspatial tasks, a further investigation of that question is warranted.

Thus, it seems that the spatial NP paradigm does not, after all, provide evidence that attentional selection is mediated by distractor inhibition. However, spatial NP may nonetheless provide an important insight about attention: that the

⁷ In the present experiments, subjects selected by symbol identity for location. In the Tipper and Cranston (1985) study, subjects selected by color for identity. Either differences in the selection-by dimension or the selection-for dimension could explain the differing results from the two tasks.

identities of unattended items are not only encoded but also bound to locations (or objects).

References

- Allport, D. A., Tipper, S. P., & Chmiel, N. R. J. (1985). Perceptual integration and postcategorical filtering. In M. I. Posner & O. S. M. Marin (Eds.), *Attention and performance* (Vol. 11, pp. 107–132). Hillsdale, NJ: Erlbaum.
- Connelly, S. L., Hasher, L., & Kimble, G. A. (1992, November). *The suppression of identity and spatial location*. Paper presented at the 33rd annual meeting of the Psychonomic Society, St. Louis, MO.
- Hunt, S. M. J. (1993). *MacProbe* [Computer program]. Woodland Hills, CA: Aristometrics.
- Johnston, W. A., & Dark, V. J. (1986). Selective attention. *Annual Review of Psychology*, *37*, 43–75.
- Jonides, J., & Mack, R. (1984). On the cost and benefit of cost and benefit. *Psychological Bulletin*, *96*, 29–44.
- Kahneman, D., Treisman, A. M., & Gibbs, B. J. (1992). The reviewing of object files: Object-specific integration of information. *Cognitive Psychology*, *24*, 175–219.
- Lowe, D. G. (1979). Strategies, context, and the mechanism of response inhibition. *Memory & Cognition*, *7*, 382–389.
- Milliken, B., Tipper, S. P., & Weaver, B. (1994). Negative priming in a spatial localization task: Feature mismatching and distractor inhibition. *Journal of Experimental Psychology: Human Perception and Performance*, *20*, 624–646.
- Neill, W. T. (1977). Inhibitory and facilitatory processes in selective attention. *Journal of Experimental Psychology: Human Perception and 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*, 389–400.
- Neill, W. T., & Valdes, L. A. (1992). Persistence of negative priming: Steady state or decay? *Journal of Experimental Psychology: Human Perception and Performance*, *18*, 565–576.
- Neill, W. T., Valdes, L. A., & Terry, K. M. (1992, November). *Negative priming in target localization*. Paper presented at the 33rd annual meeting of the Psychonomic Society, St. Louis, MO.
- 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: Human Perception and Performance*, *18*, 993–1000.
- Shapiro, K. L., & Loughlin, C. (1993). The locus of inhibition in the priming of static objects: Object token versus location. *Journal of Experimental Psychology: Human Perception and Performance*, *19*, 352–363.
- Tipper, S. P. (1985). The negative priming effect: Inhibitory effects of ignored primes. *Quarterly Journal of 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 and 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., Eissenberg, T., & Weaver, B. (1992). The effects of practice on mechanisms of attention. *Bulletin of the Psychonomic Society*, *30*, 77–80.
- Tipper, S. P., Weaver, B., Cameron, S., & Brehaut, J. (1991). Inhibitory mechanisms of attention in identification and localization tasks: Time course and disruption. *Journal of Experimental Psychology: Human Perception and Performance*, *17*, 681–692.
- Tipper, S. P., Weaver, B., & Houghton, G. (in press). Behavioral goals determine inhibitory mechanisms of selective attention. *Quarterly Journal of Experimental Psychology*.
- Treisman, A. M. (1969). Strategies and models of selective attention. *Psychological Review*, *76*, 282–299.

Received March 23, 1993

Revision received July 16, 1993

Accepted August 3, 1993 ■