Negative priming depends on probe-trial conflict: Where has all the inhibition gone?

CATHLEEN M. MOORE

University of California, San Diego, La Jolla, California

Responses to recently ignored stimuli are often slower than responses to new stimuli. This slowing—referred to as *negative priming*—has been cited as evidence that selective attention occurs, in part, through inhibition of the processing of irrelevant information, and that selection can occur at postcategorical levels of processing. While negative priming has been observed under a variety of conditions, the slowing can fail to occur if there is no information present that conflicts directly with the correct response. The failure of negative priming to occur under these conditions could provide insight into the specific source of the slowing. In five experiments, the effects of conflicting and non-conflicting information on negative priming were investigated. The results suggest that negative priming will fail to occur under nonconflict conditions only if it is quite apparent that no conflicting information is present. It is suggested that negative priming may be associated with a specific part of the selection process that is involved in protecting the person from making a response based on incorrect information, and that this process only sometimes contributes to reaction time.

The term *selective attention* refers to the process or mechanism that allows one to respond to task-relevant stimuli while not responding to irrelevant stimuli. It is assumed that in order for selective responding to occur, relevant stimuli must be processed to a greater extent than irrelevant stimuli. Logically, there are two, nonexclusive ways for this to occur. First, the processing of relevant stimuli may be facilitated; second, the processing of irrelevant stimuli may be inhibited. While many models of selective attention have been concerned with mechanisms of facilitation (e.g., Eriksen & Yeh, 1985; Neisser, 1967; Posner, 1982; Treisman & Gelade, 1980), evidence from especially demanding selective-attention tasks has led some investigators to suggest that there may also be an inhibitory component to selective attention (Keele & Neill, 1978; Neill, 1977; Tipper, 1985).

Evidence for selection through inhibition concerns the observation that responses to recently ignored stimuli are often slower than responses to new stimuli (e.g., Dalrymple-Alford & Budayr, 1966; Neill, 1977; Tipper, 1985). This slowing might be expected if selection occurred—at least in part—through specific inhibition of the processing of irrelevant stimuli. If processing of a stimulus is inhibited at one time because that stimulus is

irrelevant and the same stimulus becomes relevant soon after, there may be residual inhibition associated with it that could retard the current response. That slowing would be an indirect measure of the original inhibition.

Slowing of responses to recently ignored information was first reported from Stroop (1935) tasks in which subjects named the ink color of color-word stimuli (Dalrymple-Alford & Budayr, 1966; Neill, 1977; see MacLeod, 1991, for a review of Stroop results). When words were drawn in the color that the previous word spelled (i.e., the to-be-ignored aspect of the previous stimulus), average naming times were slower than when the words were drawn in a new color. For example, it might take longer to respond “green” to the green stimulus RED if it were preceded by the blue stimulus GREEN than if it were preceded by the blue stimulus YELLOW.

In another difficult selective-attention task, the subjects were shown displays of two different letters (often overlapping), each drawn in a different color (e.g., Tipper & Cranston, 1985). They were asked to name the letter of a specified color (target) while ignoring the other letter (distractor). Average naming times were longer to targets that were the same as the previous distractor than they were to targets that were different from the previous distractor (see also Allport, Tipper, & Chmiel, 1985; Hasher, Stoltzfus, Zacks, & Rympa, 1991; Neumann & DeSchepper, 1991). In recent years, similar slowing has been observed in selective-attention tasks that require picture naming (e.g., Tipper, 1985), word reading (e.g., Tipper & Driver, 1988), same-different judgments (e.g., Neill, Lissner, & Beck, 1990), lexical decisions (Yee, 1991), matching of abstract figures (DeSchepper & Treisman, 1991), and target localization (e.g., Tipper, Brehaut, & Driver, 1990; cf. Park & Kanwisher, in press).

While conducting this research, the author was supported by a National Science Foundation Graduate Fellowship. Special thanks are offered to Toby Mordkoff and Allen Osman for many drafts and many discussions. Thank you also to Richard Brown, Darryl Humphrey, Aaron Ilan, Art Kramer, Jeff Miller, Tram Neill, Eric Ruthruff, Ling-po Shiu, John Wixted, and three anonymous reviewers for providing helpful comments. Finally, thanks are offered to Craig Sneiderman and Deborah Stone for help with data collection. Correspondence should be addressed to C. M. Moore, Department of Psychology, University of California, San Diego, La Jolla, CA 92093-0109 (e-mail: cmoore@ucsd.edu).

The term *negative priming* has been adopted to refer to the slowing of responses to recently ignored stimuli (Tipper, 1985). The term emphasizes two important aspects of the effect. First, it classifies the slowing as a priming effect. This is appropriate because negative priming depends on events that occur previous to the time that the slowing is observed. Second, the term emphasizes that, unlike many other types of priming that seem to indicate facilitation of the processing of the same or related stimuli (e.g., Kornblum, 1973; Meyer & Schvaneveldt, 1971; Neely, 1976), negative priming appears to indicate inhibition of the processing of such stimuli.

Trials within experiments concerned with negative priming are discussed in pairs. The first trial in a pair is called the *prime*; the second is called the *probe*. Trial types refer to the probe trial, and are defined in terms of the relationship between probe trials and their prime trials. Several terminologies have been used. In the present paper, the term *ignored repetition* will be used to refer to probe trials on which the target information is the same as the distractor information on the prime trial. The term *control* will be used to refer to probe trials on which the target information is different from the distractor information on the prime trial.

Significance of Negative Priming for Selective Attention

Negative priming holds significance for our understanding of selective attention for two reasons. First, as already discussed, it is consistent with models of selective attention that maintain inhibitory components of selection. As such, it may provide a useful measure of that aspect of selection. Second, negative priming has been invoked as evidence that selection occurs at postcategorical levels of processing (i.e., after stimulus identification and classification). This view is contrary to models of selective attention that maintain that selection occurs only at precategorical levels of processing (e.g., Broadbent, 1958).

The invocation of negative priming as evidence for postcategorical selection has taken two forms. First, the slowing has been cited directly as evidence that irrelevant stimuli are processed quite deeply (Allport et al., 1985; Neill, 1977; Tipper, 1985). The argument maintains that a previously presented stimulus could interfere with the processing of a current stimulus only if it had been processed at least to the earliest level at which the two share a common representation. Within a Stroop task, for example, the word RED can interfere with naming the ink color of the following word as red. Therefore, it is argued, the word RED, though irrelevant to the task, must have been processed at least to the level of the semantic representation *red*, which it shared with the ink color of the following word. Related findings have been reported from stimulus-identification tasks. Tipper and Driver (1988) reported that ignoring the word DOG can slow naming responses to a picture of a dog. Moreover, they also reported that ignoring the word DOG can slow naming responses to the word CAT, as well as to a pic-

ture of a cat, each of which is related only categorically to the previously irrelevant information. It is argued that in order for such interference to have occurred, the irrelevant stimuli must have been processed to postcategorical levels of processing.

The second way in which negative priming has been invoked as support for postcategorical selection has been indirect. In this case, negative priming has been used as a means of undermining one class of evidence that is often used as support for precategorical selection. In this class of evidence, the absence of interference from irrelevant information within a trial is taken to demonstrate complete precategorical selection (e.g., Francolini & Egeth, 1980; Pashler, 1984). Driver and Tipper (1989) pointed out that a lack of interference from irrelevant information, as measured by reaction time or accuracy, does not require that the irrelevant information was not processed. Instead, they suggest, irrelevant information may be processed quite deeply, but may subsequently be inhibited. If this were the case, there might be no observable interference with processing of the relevant stimuli. In support of their assertion, Driver and Tipper demonstrated that under some conditions, negative priming can be observed on trials that follow trials on which no interference was observed. This indicated to them that the irrelevant information was processed during the first trial, though it caused no interference at the time. Thus, they argue, it is not necessary to conclude from a lack of interference that complete precategorical selection occurred and that the irrelevant information was not processed.

In summary, negative priming may provide insight into processes of selective attention within two previously inaccessible areas. First, it may provide a measure of inhibitory processes that are involved in selection; and second, it may provide a probe into otherwise unobservable evidence of postcategorical processing. However, responses are not slowed under all ignored-repetition conditions. The circumstances and implications of this lack of negative priming are discussed in the next two sections.

Probe-Trial Conflict

Negative priming does not occur under all conditions that involve ignored information becoming relevant information. In particular, whether or not negative priming occurs seems to depend on characteristics of the irrelevant (i.e., distracting) aspect of the probe-trial display. If an ignored-repetition probe trial includes a distractor that conflicts with the correct response (i.e., that is associated with an incorrect response), then negative priming occurs. If an ignored-repetition probe trial does not include a distractor that conflicts with the correct response, however, then negative priming may not occur. These two types of trial will be referred to, respectively, as *conflict trials* and *nonconflict trials*.

Tipper and Cranston (1985, Experiment 3; see also Allport et al., 1985, Experiment 9), for example, observed negative priming within a letter-identification task

on conflict probe trials but not on nonconflict probe trials. The subjects were asked to name red uppercase letters (targets), while they were to ignore green uppercase letters (distractors), when present. For half of the subjects, both prime and probe trials included a target and a distractor. For the other half, only prime trials included both a target and a distractor; probe trials included only a single, lowercase black letter. The subjects in the latter group were to name the single black letters as quickly as possible. Thus, probes for the first group were always conflict trials, whereas probes for the second group were always nonconflict trials. For the conflict group, if the distractor from the prime trial became the target on the probe trial, negative priming was observed. For the nonconflict group, however, if the distractor on the prime trial became the to-be-named letter on the probe trial, no slowing was observed.

Lowe (1979, Experiment 4) also found that negative priming was sensitive to probe-trial conflict, in this case within a Stroop task. He used three different types of probe-trial stimuli—color words, random-letter strings, and simple patches—all of which appeared in different colors. In all cases, the task was to name the ink color in which the stimuli were drawn; the trials differed only in the to-be-ignored aspect of the stimuli. Color-word probes were conflict trials because they named an incorrect response. In contrast, random-letter-string and simple-patch probes were both nonconflict trials because no alternative responses were associated with them. In addition to manipulating whether or not a given probe trial included response conflict, Lowe manipulated the types of probe trials that were presented to different groups of subjects. For each of three groups, probe-trial stimuli were chosen from two of the three stimulus types, such that each pairwise combination was used. Thus, for one group of subjects, probe-trial stimuli were color words or simple patches. For a second group of subjects, probe-trial stimuli were color words or random-letter strings. Finally, for the third group of subjects, probe-trial stimuli were simple patches or random-letter strings. Prime-trial stimuli for all subjects were color words.

The results demonstrated that negative priming was sensitive to probe-trial conflict, but that it could occur on nonconflict probe trials under some conditions. Significant negative priming was always observed on color-word probe trials, but never on simple-patch probe trials. Unlike for color words and simple patches, however, whether negative priming occurred on random-letter-string probe trials depended on what the other probe-trial stimuli were. In particular, when the other probes were simple-patch trials, no significant negative priming was observed; when the other probes were color-word trials, however, negative priming was observed on the random-letter-string probes, even though they were nonconflict trials.

Lowe's (1979) results indicate that the context in which nonconflict trials are presented can affect whether negative priming occurs. The results of several other

studies corroborate this dependence. Neill and Westberry (1987, Experiments 1 and 2), for example, asked subjects to report the color of letter-string stimuli. Some of the letter strings were nonconflict, noncolor words (ooo, oooo, ooooo, and oooooo), and others were conflict, color words. Conflict and nonconflict trials occurred randomly within the experiment, and negative priming was observed on both conflict and nonconflict probe trials. In another task, Neill, Terry, and Valdes (1994) asked subjects to report the location of a target stimulus (*O*) while ignoring the location of a distractor stimulus (*X*). Negative priming was observed in the form of slowed report of locations for targets that appeared in the same place as the distractor from the preceding (prime) trial. Probe trials randomly included a distractor (conflict) or no distractor (nonconflict), and the slowing was observed on both types of probe trial. In contrast, using the same task in an experiment in which all probes were nonconflict, Tipper et al. (1990, Experiment 5) reported no significant negative priming.

Finally, negative priming has been observed on nonconflict probe trials even when all probes were nonconflict trials (Yee, 1991, Experiments 1 and 2). Unlike in the previous studies that have been described, the subjects in these experiments completed different tasks on the prime and probe trials. The task on the probe trials was a lexical-decision task (i.e., deciding whether a letter string is a word or a nonword), whereas the task on the prime trials was a form-identification task. On the latter, geometrical forms were presented in the center of the displays with one or two words above and/or below the forms; while ignoring the word(s), the subjects identified the geometrical form by pressing an assigned button. On probe trials, one letter string that was either a word or a nonword was presented at the center of the display. Negative priming was observed on the probe trials when two words had been presented on the prime trial and one had been related to the probe-trial stimulus (see Fuentes & Tudela, 1992, for similar results).

In summary, negative priming seems to be sensitive to probe-trial conflict. This sensitivity, however, seems to depend, in turn, on other characteristics of the experiment in which the conflict and nonconflict trials occur. In the present study, the effects of probe-trial conflict on negative priming were investigated in five experiments. The results suggest that negative priming will fail to occur on nonconflict probe trials only when they can be identified easily as including no information that could conflict with the correct response. Before providing an overview of the experiments, however, the significance of the probe-trial conflict problem and its resolution is discussed.

Significance of the Effects of Probe-Trial Conflict on Negative Priming

That negative priming can depend on whether a probe trial includes information that conflicts with the correct response has raised some concern regarding inhibitory-selection views of negative priming. It has been argued

that a simple model of inhibition, wherein the slowing depends on residual suppression of internal representations of the previous distractor (e.g., Neill, 1977), cannot account for negative priming, given its dependence on probe-trial conflict (Allport et al., 1985; Lowe, 1979; Tipper & Cranston, 1985). According to these arguments, manipulations of the probe trial should not affect negative priming, because the inhibition is supposed to have occurred during the prime trial. By the time the probe trial occurs, the damage should have been done.

These arguments, however, apply to a particular version of inhibitory selection. According to that version, responses depend on activation of internal stimulus codes reaching threshold levels. The activation of codes that represent the identity of distractors is suppressed. Once a trial is complete, the suppressed code resolves passively back to baseline levels. Negative priming is observed when a target stimulus with the same identity as a recently suppressed stimulus is presented before the suppressed code has resolved back to baseline levels. While arguments could be made that manipulations of the probe trial can affect either the rate at which the suppressed code resolves back to baseline or the threshold level of activation for eliciting a response, there is nothing in the basic model that predicts that negative priming should fail to occur on nonconflict probe trials.

There are at least two alternative classes of models of inhibitory selection, however, for which the dependence of probe-trial conflict presents no problem. In the first of these, rather than responses being based on absolute levels of activation, as in the basic model described above, responses may be based on relative levels of activation (e.g., Houghton & Tipper, 1994). According to this type of model, a response might be based on the first stimulus representation to become sufficiently more activated than any other stimulus representation, where "sufficiently" refers to a variable threshold difference. If a target representation were residually inhibited, it might take longer for that representation to become sufficiently more activated than for distractor representations to do so. If, however, no competing code were activated—such as on a nonconflict trial—the target stimulus might immediately be sufficiently more activated than any other representation, and no negative priming would be observed.

In the second alternative class of models, inhibitory selection may not function through the inhibition of code activations at all. Instead, negative priming may manifest slowing or inhibition of a specific process that only sometimes contributes to reaction time. If that process contributes to reaction time on the probe trial, residual inhibition will be observed in the form of negative priming; if it does not, the inhibition will go unnoticed, and no negative priming will be observed. As an analogy, imagine that a member of a relay team has suffered a pulled muscle. If the injured person does not run in the race, or if the injured person does run in the race but a teammate makes up the difference in running time, the injury will not be reflected in the overall relay time. Only

if the injured runner runs in the race and all other participants run normally will the injury be reflected in the relay time. The fact that changes in conditions at the time of the race can affect whether or not the injury is reflected in the relay time need not raise concern regarding when the injury took place or whether the injury took place. If a specific-process model applies to negative priming, then, rather than raising concern regarding inhibitory-selection interpretations of negative priming, the failure of the slowing under some conditions may help identify what process is affected through inhibitory selection.

Overview

The effects of probe-trial conflict on negative priming were investigated in five experiments. The task in each experiment was a letter-identification task. Two factors were manipulated that were intended to affect how easily probes could be identified as conflict or nonconflict trials: (1) the *context* in which conflict and nonconflict probe trials occurred (i.e., whether, within a block, probes were randomly conflict or nonconflict trials or were all one or the other); and (2) the *similarity* between conflict and nonconflict trials. Nonconflict probe trials that appeared in blocks in which all probes were nonconflict were predictably nonconflict, whereas nonconflict probe trials that appeared in blocks in which probes were randomly conflict and nonconflict were unpredictable; similarly, nonconflict probe trials that were quite distinct from conflict trials could be identified easily as nonconflict, whereas those that were quite similar to conflict trials could not.

Context was manipulated within each of the first four experiments; similarity was manipulated between experiments. Nonconflict trials were the least similar to conflict trials in Experiment 1 and the most similar in Experiment 2. Experiments 3 and 4 were designed to provide intermediate levels of similarity between conflict and nonconflict trials. The results of the first four experiments were consistent with the hypothesis that negative priming will fail to occur on nonconflict probe trials only when they can be identified easily as nonconflict. Experiment 5 provided a more direct test of this hypothesis.

GENERAL METHOD

Subjects

Sixteen subjects from the University of California, San Diego undergraduate subject pool were tested in each of the experiments described below. All were between the ages of 18 and 26 years. None of the subjects participated in more than one of the experiments. In compensation for their time, they received experimental credit which was required for an introductory course in psychology. All of the subjects were naive as to the purpose of the experiment prior to participating, and all reported having normal or corrected-to-normal visual acuity and color vision.

Apparatus and Stimuli

Stimuli were light blue (cyan) or white (EGA/VGA four-bit palette codes 11 and 15) uppercase letters (sans serif), pound signs (#), and random-dot fields which were presented centrally on a

dark background of a VGA color monitor. Target letters (*I*, *O*, *S*, and *X*) were chosen, which could be easily discriminated from each other. Each stimulus subtended approximately $1.15^\circ \times 0.91^\circ$ from a typical viewing distance of 50 cm. The random-dot fields were generated by defining a letter-sized rectangle and illuminating a random 15% of the pixels within that region.

Two stimuli (one light blue and one white) were often presented simultaneously such that they overlapped. Overlap was determined by randomly choosing two points from among the 45° , 130° , 225° , and 315° positions of an imaginary circle that was 0.18° of visual angle in diameter. These points served as the centers of the two stimuli. Which stimulus was drawn last—and therefore appeared to be in front—was determined randomly for each trial. Trial events and data collection were controlled by an AT-compatible microcomputer.

Task

The task in each of the first five experiments was four alternative, forced choice. Each subject was assigned a target color (light blue or white). On each trial, the subject was shown one or two stimuli and was asked to respond to the letter of the target color while ignoring any other stimuli. (In Experiments 1–4 there was always exactly one letter of the target color on each trial. Experiment 5 is described in more detail below.) Responses were made with the four fingers of the dominant hand on the “M,” “<,” “>,” and “?” keys of the computer keyboard if the subject was right-handed, and on the “Z,” “X,” “C,” and “V” keys if the subject was left-handed. Letters were randomly assigned to each of the four response fingers for each subject.

Design

In each experiment, odd-numbered trials were prime trials and even-numbered trials were probe trials. Prime trials always included two letters chosen from the target set—a target and a distractor. The distractor, if any, on the probe trial varied across experiments. Only the data recorded from the probe trials are reported. (Prime-trial data were analyzed in an analogous manner to probe-trial data, but no reliable effects were revealed.) In all experiments, half of the subjects were assigned blue and the other half were assigned white as the target color.

A $2 \times 2 \times 2$ within-subjects design was used in each of the first four experiments (see separate Method section for the design of Experiment 5). The factors were trial type, conflict, and context. The two trial types were ignored repetition and control, which are defined by the relationship between prime and probe trials: Ignored-repetition trials are those in which the target on the probe trial is the same as the distractor on the prime trial, and the two trials have no other stimuli in common; control trials are those in which all of the stimuli on the probe trial are different from all of the stimuli on the prime trial. For both ignored-repetition and control trials, the target and distractor within each display (i.e., prime and probe) must be different from each other. Examples of these two trial types are illustrated in Figure 1.

Conflict refers to whether a probe trial included a distractor that conflicted with the correct response (conflict) or not (nonconflict). Conflict probe trials included a distractor that was chosen from the target set. Nonconflict probe trials included either no distractor or a distractor that was not from the target set. The specifics of the nonconflict probe trials are described separately in more detail for each experiment below.

Context refers to whether blocks included only conflict or only nonconflict probe trials (pure) or whether they included both conflict and nonconflict probe trials (mixed). The subjects received a message at the beginning of each block indicating what kind of block it would be. The messages took the following forms: “In the next block, every trial will include two letters” or, “In the next block, every other trial will include only one letter,” for the pure blocks, and, “In the next block, trials will randomly include one

Figure 1. A schematic illustration of a control prime-probe pair of trials and an ignored-repetition prime-probe pair of trials. Time is shown flowing from left to right. Each pair of letters represents a single trial display. The subjects are asked to respond to the target letter while ignoring the distractor letter. The target on the probe trial in the ignored-repetition condition is the same letter as the distractor on the prime trial; the target on the probe trial in the control condition is a different letter from both the target and the distractor on the prime trial.

or two letters” for the mixed blocks. The messages varied slightly across experiments in order to accommodate the different types of nonconflict trial. Half of the blocks were pure; the other half were mixed. Of the pure blocks, half consisted of conflict probe trials only and the other half consisted of nonconflict probe trials only. The different block types were presented in pairs such that two blocks of one type (e.g., mixed) were presented, then two of another type (e.g., pure, conflict only), and so on, were presented. Every other pair of blocks was a pair of mixed blocks. Four different orders of block presentation were counterbalanced across subjects.

The target and distractor for each prime trial and each conflict probe trial were chosen randomly from the target set. Distractors, if any, for each nonconflict probe trial were chosen randomly from the set of nonconflict distractors used in the given experiment (discussed separately below for each experiment). Subsequent to data collection, trials were defined as control, ignored repetition, or neither, based on the relationship between the current probe trial and its prime trial. Thus, except for the set from which they were drawn, stimuli were chosen with no constraints.

Procedure

Each subject participated in a single 1-h session. They were first given written instructions that described the task. Each then completed approximately 96 practice trials that were presented in four short blocks (two mixed and two pure). After each error during the practice blocks, the target letters were presented on the monitor in the order corresponding to the correct buttons to remind the subject of the letters-to-buttons mapping. The data from practice blocks were not recorded. Postpractice instructions emphasized that responses should be made as quickly as possible, while no more than 5% errors should be made within a given block. The subjects then completed 24 blocks of 60 trials each (30 prime trials and 30 probe trials). For both the practice and the experimental blocks, mean reaction time and percentage of correct trials from the previous block were displayed during a 10-sec forced rest period that occurred between blocks. Except during practice, if subjects were less than 95% accurate on a given block, they were advised to “slow down and make fewer errors.” After the forced rest period, the subjects initiated the next block when they were ready by pressing any key on the keyboard.

Each trial began with the presentation of a white $0.23^\circ \times 0.17^\circ$ plus sign (+) at the center of the monitor which served as a fixation marker. The plus sign remained illuminated for 250 msec and was followed by a blank, dark field. One or two colored letters appeared at the center of the monitor 100 msec following the offset

of the plus sign. The display was removed upon response and was replaced with the plus sign for the following trial 150 msec later. Incorrect responses were indicated by a 150-msec descending tone (1000–10 Hz) and were followed by a 2,000-msec "time-out," during which the screen was blank. Responses made prior to 150 msec following display presentation were considered errors, whether or not they were correct.

EXPERIMENT 1

In the first experiment, nonconflict probe trials included no distractor; targets were presented alone. Conflict trials included both a target and a distractor that were chosen from the target set. Half of the blocks were pure, such that all probe trials were conflict trials or all probes were nonconflict trials. The other half of the blocks were mixed, such that probes were randomly conflict or nonconflict trials.

There were two goals of Experiment 1: (1) to replicate the elimination of negative priming on nonconflict probe trials when all probes were nonconflict; and (2) to test whether mixing conflict and nonconflict probe trials within blocks—such that the subjects could not predict what type of trial a given probe would be—would cause negative priming to reappear on nonconflict probe trials.

Method

All prime trials and all conflict probe trials included both a target and a distractor that were chosen from the target set. Nonconflict probe trials included only a target. The effect of context on negative priming was tested by comparing conflict and nonconflict probe trials from pure blocks with conflict and nonconflict probe trials from mixed blocks.

Results

Mean correct probe-trial RTs from Experiment 1 (presented in Figure 2) were submitted to a 2 (ignored repetition, control) $\times$ 2 (conflict, nonconflict) $\times$ 2 (pure, mixed) repeated measures analysis of variance (ANOVA). The three-way interaction between trial type, conflict, and context was not significant ($F < 1$). This indicates that the pattern of negative priming as a function of probe-trial conflict did not differ significantly between the pure and mixed conditions. The two-way interaction between trial type and conflict was significant [$F(1,15) = 16.64$, $p < .001$]. This interaction can be seen in both the upper and lower panels of Figure 2; negative priming was observed when there was a distractor in the probe display, but not when there was no distractor. Planned comparisons (two-tailed Student's t) confirmed that, in both the pure and mixed conditions, ignored-repetition RTs were significantly longer than control RTs when there was a distractor present [pure: $t(15) = 2.79$, $p < .05$; mixed: $t(15) = 3.75$, $p < .005$], but not when there was no distractor present ($t < 1$ for both pure and mixed).

Error rates. Error rates (ERs) are given in Table 1. The same analyses were run on the arcsine transformations of the ERs. The omnibus ANOVA revealed a significant three-way interaction between trial type, conflict, and context [$F(1,15) = 5.04$, $p < .05$]. However, no

Figure 2. Mean correct probe-trial RTs from Experiment 1. The top panel shows ignored-repetition and control RTs for conflict and nonconflict probe trials in pure blocks, and the bottom panel shows ignored-repetition and control RTs for conflict and nonconflict probe trials in mixed blocks.

other reliable ($\alpha = .05$) effects were found through further analyses.

Discussion

Negative priming was sensitive to probe-trial conflict: significant negative priming was observed on conflict probe trials, but not on nonconflict probe trials. However, negative priming on nonconflict probe trials did not reappear when it was impossible for subjects to predict that the probe trials would be nonconflict; pure and mixed blocks yielded the same pattern of results.

Why did context seem to affect negative priming on nonconflict probe trials in previous studies (Lowe, 1979; Neill et al., 1994; Neill & Westberry, 1987; Tipper et al., 1990), but not in the present experiment, in which context was manipulated directly? The singleton characteristic of nonconflict probe trials in the present experiment may

Table 1
Error Rates (%) for Experiments 1-5

Experiment	Conflict		Nonconflict	
	Control	Ignored Repetition	Control	Ignored Repetition
Pure				
1	5.8	3.8	1.6	4.3
2	4.6	5.1	5.0	2.5
3	5.6	4.2	4.3	3.0
4	3.3	4.3	3.9	6.3
5				
Mixed				
1	1.8	4.1	3.9	2.9
2	4.0	4.1	2.7	5.1
3	4.4	5.5	4.6	5.6
4	3.3	7.0	4.9	2.7
5	4.4	5.7	6.5	3.6

have allowed subjects to identify them extremely quickly—even in the mixed blocks—as including no information that could conflict with the correct response. Perhaps if the nonconflict probe trials were not as distinct from conflict trials, negative priming would have occurred on nonconflict probe trials in the mixed blocks. This hypothesis was tested in Experiment 2.

EXPERIMENT 2

Nonconflict probe trials in Experiment 2 were designed to be more similar in appearance to conflict trials than were those in Experiment 1. Unlike nonconflict probe trials in Experiment 1, those in Experiment 2 included both a target and a distractor. Thus, nonconflict probe trials could not be distinguished from conflict probe trials based on the salient singleton characteristic. As in Experiment 1, however, nonconflict probe trials included no information that conflicted directly with the correct response; distractors were chosen from a set of letters that were not associated with a response. If the singleton characteristic of nonconflict probe trials in Experiment 1 allowed subjects to identify those trials as nonconflict extremely easily, and thereby allowed negative priming to fail to occur, then negative priming might reappear on nonconflict probe trials in the mixed blocks of Experiment 2. Negative priming should still fail to occur on the nonconflict probe trials in the pure blocks, however, because those probe trials could be predicted as nonconflict.

Method

Ignored-repetition and control RTs from conflict probe trials were again compared with ignored-repetition and control RTs from nonconflict probe trials, under both pure and mixed conditions. Conflict probe trials were the same as those in Experiment 1. Nonconflict probe trials included both a target and a distractor. Targets were chosen from the target set, whereas distractors were chosen from the set *A*, *F*, *N*, and *P*. These will be referred to as *nonresponse-letter* distractors.

Results

Mean correct probe-trial RTs from Experiment 2 (presented in Figure 3) were subjected to a 2 (ignored repetition, control) $\times$ 2 (conflict, nonconflict) $\times$ 2 (pure, mixed) repeated measures ANOVA. Unlike in Experiment 1, the three-way interaction between trial type, conflict, and context was significant [$F(1,15) = 6.36$, $p < .05$; see Figure 3]. When probe-trial distractors within a block were always nonresponse letters or always response letters (top panel, Figure 3), whether negative priming occurred depended on the type of distractor [$F(1,15) = 7.82$, $p < .05$]. In contrast, when probe-trial distractors within a block were randomly nonresponse letters or response letters (bottom panel, Figure 3), negative priming was observed regardless of the type of distractor ($F < 1$). Planned comparisons (two-tailed Stu-

Figure 3. Mean correct probe-trial RTs from Experiment 2. The top panel shows ignored-repetition and control RTs for conflict and nonconflict probe trials in pure blocks, and the bottom panel shows ignored-repetition and control RTs for conflict and nonconflict probe trials in mixed blocks.

dent's t) confirmed that in the pure condition, ignored-repetition RTs were longer than control RTs on conflict probe trials [$t(15) = 3.72, p < .05$], but not on nonconflict probe trials ($t < 1$). In the mixed condition, however, ignored-repetition RTs were longer than control RTs on both conflict probe trials [$t(15) = 3.25, p < .05$] and nonconflict probe trials [$t(15) = 4.00, p < .005$].

Error rates. The same analyses were run on the arcsine transformations of the ERs (ERs shown in Table 1). No significant ($\alpha = .05$) effects were revealed from the ANOVA or the specific comparisons.

Discussion

When nonconflict probe trials could be neither predicted nor easily identified as nonconflict (i.e., in the mixed blocks), negative priming occurred on both conflict and nonconflict probe trials. When probes could be predicted to be nonconflict (i.e., in the pure-nonconflict blocks), however, negative priming failed to occur. These results support the hypothesis that negative priming failed to occur on nonconflict probe trials in the mixed blocks of Experiment 1 because the singleton characteristic allowed subjects to quickly identify those trials as nonconflict. The results of both Experiments 1 and 2, therefore, are consistent with the general hypothesis that negative priming will fail to occur on nonconflict probe trials only when they can be identified easily as including no information that could conflict with the correct response.

How similar to conflict trials do nonconflict probe trials have to be in order for negative priming to occur? Conflict and nonconflict trials differed in Experiment 2 only in the set of letters from which their distractors were chosen. Therefore, it may have been extremely difficult to distinguish between the two types of trial. Experiment 3 tests whether negative priming can be observed on nonconflict probe trials that are less similar in appearance to conflict trials than those that included nonresponse-letter distractors (Experiment 2), but still more similar than those that included no distractor (Experiment 1).

EXPERIMENT 3

As in Experiment 2, nonconflict probe trials in Experiment 3 included both a target and a distractor. The nonconflict distractors in Experiment 3, however, were all pound signs (#). Thus, the distractors on nonconflict trials were always the same, and, unlike those on conflict trials, they were not uppercase letters. These nonconflict trials should have been more discriminable from conflict trials than were those that included distractors chosen from a set of four different nonresponse letters (Experiment 2). They should have been less discriminable, however, than those that included no distractor (Experiment 1).

Method

Once again, ignored-repetition and control RTs from conflict probe trials were compared with ignored-repetition and control RTs from nonconflict probe trials, under both pure and mixed conditions. Conflict probe trials were the same as in the previous two experiments. Nonconflict probe trials included a target from the target set and a pound-sign (#) distractor that was the same size as the letter stimuli.

Results

Mean correct probe-trial RTs from Experiment 3 (presented in Figure 4) were subjected to a 2 (ignored repetition, control) $\times$ 2 (conflict, nonconflict) $\times$ 2 (pure, mixed) repeated measures ANOVA. The three-way interaction between trial type, context, and conflict was significant [$F(1,15) = 7.60, p < .05$]. Negative priming

Figure 4. Mean correct probe-trial RTs from Experiment 3. The top panel shows ignored-repetition and control RTs for conflict and nonconflict probe trials in pure blocks, and the bottom panel shows ignored-repetition and control RTs for conflict and nonconflict probe trials in mixed blocks.

depended on conflict in pure blocks [upper panel, $F(1,15) = 14.73$, $p < .005$], but not in mixed blocks (lower panel, $F < 1$).

Planned comparisons (two-tailed Student's t) confirmed that, in the pure blocks, ignored-repetition RTs were longer than control RTs on conflict probe trials [$t(15) = 5.26$, $p < .005$], but not on nonconflict probe trials ($t < 1$). In the mixed blocks, however, ignored-repetition RTs were longer than control RTs on both conflict probe trials [$t(15) = 2.77$, $p < .01$] and nonconflict probe trials [$t(15) = 2.79$, $p < .01$].

Error rates. The same analyses were run on the arcsine transformations of the ERs for each experiment (ERs given in Table 1). No significant ($\alpha = .05$) effects were found.

Discussion

Once again, when it was impossible to predict whether probe trials would be conflict or nonconflict (i.e., in the mixed blocks), negative priming occurred on both types of probe trial. When probe trials could be predicted to be nonconflict (i.e., in the pure-nonconflict blocks), negative priming failed to occur. It appears that the nonconflict probe trials with pound-sign distractors were sufficiently similar to conflict probe trials that they could not be identified quickly as nonconflict and, therefore, when they could not be predicted to be nonconflict, negative priming occurred.

EXPERIMENT 4

It has been argued that negative priming failed to occur on the singleton-target nonconflict probe trials of Experiment 1 because the singleton characteristic allowed subjects to identify those trials quickly and easily as nonconflict. This hypothesis was supported in that negative priming did occur on nonconflict probe trials in the mixed blocks of Experiments 2 and 3, in which nonconflict probe trials included both a target and a distractor. These nonconflict probe trials, however, differed from the singleton-target nonconflict probe trials of Experiment 1 not only in that they were less discriminable from conflict trials, but also in that they included stimuli of both the target and the distractor color. It may be that the presence of the distractor color, rather than the decreased discriminability between conflict and nonconflict probe trials, caused negative priming to occur in Experiments 2 and 3. Experiment 4 tested this possibility.

Nonconflict probe trials in Experiment 4 included a target and a letter-sized field of random dots that was drawn in the distractor color. Because the random dots looked nothing like an uppercase letter, it was assumed that these nonconflict probe trials would be quite distinct from conflict trials. However, they did include stimuli of both the target color and the distractor color. Therefore, if negative priming failed to occur on the singleton nonconflict probe trials of Experiment 1 because they included no stimulus of the distractor color, negative prim-

ing should be observed on nonconflict probe trials in the mixed blocks of Experiment 4. If, however, negative priming failed to occur on the singleton nonconflict probe trials of Experiment 1 because they were easily distinguishable from conflict probe trials, no negative priming should be observed on nonconflict probe trials in Experiment 4.

Method

As before, ignored-repetition and control RTs from conflict probe trials were compared with ignored-repetition and control RTs from nonconflict probe trials, under both pure and mixed conditions. Conflict probe trials were the same as in the previous two experiments. Nonconflict probe trials included a target from the target set and a letter-sized field of random dots (see Apparatus and Stimulus section under General Method).

Results

Mean correct probe-trials RTs for probe trials from Experiment 4 (presented in Figure 5) were subjected to a 2 (ignored-repetition, control) $\times$ 2 (conflict, nonconflict) $\times$ 2 (pure, mixed) repeated measures ANOVA. The three-way interaction between trial type, context, and conflict was not significant ($F < 1$). Negative priming depended on conflict in both pure (upper panel, Figure 5) and mixed (lower panel, Figure 5) blocks [overall conflict $\times$ context interaction: $F(1,15) = 7.24$, $p < .05$].

Planned comparisons (two-tailed Student's t) confirmed that, regardless of context, ignored-repetition RTs were slower than control RTs on conflict probe trials [pure: $t(15) = 3.08$, $p < .025$; mixed: $t(15) = 3.91$, $p < .005$], but not on nonconflict probe trials ($t < 1$ for both pure and mixed).

Error rates. The same analyses were run on the arcsine transformations of the ERs (ERs given in Table 1). The three-way interaction between trial type, conflict, and context was significant [$F(1,15) = 6.51$, $p < .05$]. However, no other reliable ($\alpha = .05$) effects were revealed either from further ANOVAs or from the specific comparisons.¹

Discussion

The results indicate that the failure of negative priming to occur on nonconflict probe trials in Experiment 1 was not caused by a lack of the distractor color. Nonconflict probe trials in Experiment 4 included stimuli of both the target color and the distractor color, yet no negative priming was observed on these trials in either the mixed or the pure blocks. Therefore, the failure of negative priming to occur on the nonconflict probe trials of both Experiments 1 and 4 is best attributed to the distinctness of the nonconflict probe trials from the conflict trials in these experiments.²

EXPERIMENT 5

The results of the first four experiments suggest that negative priming will fail to occur on nonconflict probe trials only when they can be identified easily as includ-

Figure 5. Mean correct probe-trial RTs from Experiment 4. The top panel shows ignored-repetition and control RTs for conflict and nonconflict probe trials in pure blocks, and the bottom panel shows ignored-repetition and control RTs for conflict and nonconflict probe trials in mixed blocks.

ing no information that could conflict with the correct response. Experiment 5 provides a more direct test of this hypothesis. The strategy was to demonstrate that negative priming can occur on nonconflict probe trials that previously yielded no negative priming (i.e., the singleton-target probe trials of Experiment 1) when those nonconflict probe trials can no longer be easily identified as nonconflict.

Nonconflict probe trials were exactly the same as those used in Experiment 1 (i.e., singleton targets). Thus, within the domain of the present study, they were maximally dissimilar from the two-stimulus conflict trials (see note 2). In addition to the normal two-stimulus conflict trials, however, some conflict probe trials included singleton distractors that were chosen from the target set. On these trials, the subjects were to withhold

responding. Thus, the subjects could not use the singleton characteristic of the nonconflict trials to identify them as nonconflict. If they were to do so, they would run the risk of incorrectly responding to a singleton-distractor trial. If negative priming fails to occur only when probe trials can be identified easily as nonconflict, negative priming should be observed on the nonconflict probe trials in Experiment 5. This would be a particularly informative result, because no negative priming was observed on these trials in Experiment 1.

Method

Except where indicated in the next two sections, the method of Experiment 5 was the same as that used in Experiments 1–4.

Design. Because the introduction of singleton-distractor probe trials reduced the number of observations within the relevant conditions (i.e., ignored repetition and control), the block manipulation was eliminated. All blocks were mixed; probes were randomly conflict or nonconflict trials. Half of the probes were conflict trials that included both a target and a distractor that were chosen from the target set; one quarter were nonconflict trials that included only a target that was chosen from the target set; and the remaining one quarter were conflict trials that included only a distractor (*singleton-distractor probe trials*) that was chosen from the target set.

Procedure. As in the first four experiments, each trial began with the presentation of a white plus sign as a fixation marker. The plus sign remained illuminated for 250 msec and was followed by a blank, dark field. One or two colored letters (light blue and/or white) appeared at the center of the monitor 100 msec following the offset of the plus sign. If a correct response was made, the letters disappeared and were replaced by the plus sign for the following trial. If an incorrect response was made (either because the trial required no response or because it required a different response), the error tone was presented and was followed by a 2,000-msec “time-out,” during which the screen was blank. If responding was appropriately withheld on a singleton-distractor probe trial, the letter disappeared after 2,000 msec and was replaced by the plus sign for the following trial 150 msec later. If no response

Figure 6. Mean correct probe-trial RTs from Experiment 5. Ignored-repetition and control RTs for conflict and nonconflict probe trials are shown. All blocks were mixed in Experiment 5.

was made after 2,000 msec following any other type of trial, the error tone occurred and was followed by a 2,000-msec "time-out." Finally, instead of four short practice blocks and 24 sixty-trial experimental blocks, the subjects completed one sixty-trial practice block and 22 sixty-trial experimental blocks.

Results

Mean correct probe-trial RTs from Experiment 5 (presented in Figure 6) were subjected to a 2 (ignored repetition, control) $\times$ 2 (conflict, nonconflict) repeated measures ANOVA. Both main effects were significant [trial type: $F(1,15) = 41.38, p < .001$; conflict: $F(1,15) = 20.60, p < .001$], and the interaction approached significance [$F(1,15) = 3.44, p < .10$]. Planned comparisons (two-tailed Student's t) confirmed that ignored-repetition RTs were significantly slower than control RTs for both conflict [$t(15) = 2.78, p < .05$] and nonconflict [$t(15) = 3.89, p < .01$] probe trials.

Error rates. The same analyses were run on the arcsine transformations of the ERs (ERs given in Table 1). No significant ($\alpha = .05$) effects were found.

Discussion

The results of Experiment 5 support the hypothesis that negative priming will fail to occur on nonconflict probe trials only when they can be identified easily as including no information that could conflict with the correct response. Negative priming failed to occur on singleton-target (nonconflict) probe trials in Experiment 1, in which there were no singleton-distractor (conflict) probe trials. Negative priming did occur, however, on singleton-target probe trials in Experiment 5, in which singleton-distractor probe trials were included in the design. The singleton-target probe trials could be identified easily as nonconflict in Experiment 1 based on the singleton characteristic, but could not in Experiment 5. Thus, negative priming failed to occur in Experiment 1, but not in Experiment 5.

GENERAL DISCUSSION

Negative priming has been interpreted as manifesting an inhibitory component of selective attention and has been invoked as evidence that at least part of the selection process occurs at postcategorical levels of processing. It was discovered that negative priming will often fail to occur if there is no conflicting information present when a person responds to a recently ignored stimulus (Lowe, 1979). This failure of negative priming is likely to offer insight into the specific source of the slowing, and perhaps thereby into mechanisms of selection through inhibition. The present study was concerned with identifying more precisely the conditions under which negative priming can be expected to fail to occur, with regard to probe-trial conflict.

The results support the hypothesis that negative priming will fail to occur on nonconflict probe trials only when they can be identified easily as including no information that could conflict with the correct response.

Two factors that can affect how easily nonconflict probe trials can be identified as nonconflict were considered in the present study: the *predictability* of whether or not a probe trial will be nonconflict (as manipulated through context); and the *similarity* between conflict and nonconflict trials. Consistent with the stated hypothesis, negative priming failed to occur only when probes were predictably nonconflict trials (pure blocks, Experiments 1–4) or when they could be easily discriminated from conflict trials (Experiments 1 and 4). Otherwise, negative priming was observed on both conflict and nonconflict probe trials (mixed blocks, Experiments 2 and 3; Experiment 5).

The results of several previous studies are also consistent with the hypothesis that negative priming will fail to occur on nonconflict probe trials only when they can be identified easily as nonconflict (Lowe, 1979; Neill et al., 1994; Neill & Westberry, 1987; Tipper et al., 1990; Tipper & Cranston, 1985). However, although this may be a necessary condition, a set of results reported by Yee (1991; see also Fuentes & Tudela, 1992) indicates that presenting easily identifiable nonconflict probe trials is not a sufficient condition for negative priming to fail to occur. The subjects in Yee's study performed a form-identification task on prime trials and a lexical-decision task on probe trials. All probes were nonconflict and none were similar to conflict trials, yet negative priming occurred. Whatever served to eliminate negative priming on nonconflict probe trials for simple identification tasks did not do so for this more complicated lexical-decision task. In the following sections, some reasons why negative priming might sometimes fail to occur are discussed.

Negative Priming Within Houghton and Tipper's Model of Selective Attention

As mentioned briefly in the introduction, Houghton and Tipper (1994) have presented a model of selective attention that can account for the failure of negative priming to occur on probe trials that include no distractors. Theirs is a connectionist model in which stimulus representations compete for access to response mechanisms. The competition is based on the relative levels of activation between stimulus representations; when one stimulus becomes sufficiently more activated than any other stimulus, it gains access to response mechanisms, and a response is executed based on that stimulus. According to the model, selective attention involves both facilitation of target-activation growth and inhibition of distractor-activation growth; both serve to speed the resolution of the competition process.

Within this model, negative priming is caused by the competition for access to response mechanisms being prolonged on ignored-repetition probe trials relative to that on control probe trials. Target representations on ignored-repetition probe trials are less activated than their control counterparts because they were inhibited as distractors on the previous trial (i.e., the prime trial). Because of this diminished activation, it takes longer for tar-

gets to win the competition on ignored-repetition probe trials than on control probe trials. For this reason, the time required to execute a response is greater on ignored-repetition probe trials than on control probe trials.

Because negative priming reflects a prolongation of this competition process, the model predicts that negative priming will not occur if probe trials do not include a distractor (e.g., nonconflict probe trials in the present Experiment 1). This follows because when there is no competing stimulus present, the target will immediately "win" the competition. With no distractor, there will be no prolongation of the competition because, effectively, there will be no competition to be prolonged. Thus, no negative priming will be observed.

Although this model can account for the basic nonconflict effect, it cannot account for the occurrence of negative priming on nonconflict probe trials in Experiment 5 of the present study. As in Experiment 1, nonconflict probe trials in Experiment 5 included no distractor. Therefore, there should have been no competition, and negative priming should have failed to occur. Contrary to this prediction, negative priming was observed on singleton-target probe trials in Experiment 5. Models such as that described by Houghton and Tipper (1994), that account for negative priming in terms of relative levels of activation, and do not require a criterion level of activation to elicit a response, cannot account for this result.

A Memory-Retrieval Model of Negative Priming

Neill, Terry, and Gorfein (1992) have presented a model that accounts for the failure of negative priming to occur on nonconflict probe trials by abandoning the notion of inhibitory selection. According to this model, negative priming is caused—during the probe trial—by retrieval of information from the prime trial that conflicts with the current, correct response. Following Logan (1988), they assume that attending to a stimulus causes previous instances of that stimulus to be retrieved from memory. For ignored-repetition probe trials, the most recent previous instance of the attended stimulus is the prime trial, during which the stimulus was a distractor and responses to it were inappropriate. Thus, the information that is retrieved during an ignored-repetition probe trial is information that conflicts with the current, correct response.

Neill et al. (1992) suggested two reasons that retrieval of conflicting information from the prime trial might cause slowed responding on ignored-repetition probe trials. First, it might interfere with responding in the same way that conflicting information gained from within a single trial interferes with responding (e.g., B. A. Eriksen & C. W. Eriksen, 1974; Stroop, 1935). Second, retrieval of conflicting information might cause there to be less-than-sufficient response information, forcing subjects to rely on slower processes to derive the appropriate response (after Logan, 1988).

As mentioned, the memory-retrieval model can account for the failure of negative priming to occur on

probe trials that include no distractor (e.g., nonconflict probe trials in Experiment 1 of the present study). There is evidence that previous events are most likely to be retrieved when the circumstances at the time of retrieval are most similar to those at the time of initial encoding (e.g., Tulving & Osler, 1968; Tulving & Thomson, 1973). In the present context, the time of retrieval is the probe trial and the time of initial encoding is the prime trial. Perhaps retrieval of prime-trial information is more likely to be successful when probes are similar to their primes than when they are dissimilar. If this were the case, then given that prime trials include two stimuli (i.e., a target and a distractor), retrieval of prime-trial information would be more likely to occur on two-stimulus probe trials than on one-stimulus probe trials. Thus, according to the memory-retrieval model, negative priming fails to occur on probe trials that include no distractor because they are relatively unlikely to elicit a retrieval of conflicting information from the prime trial.

In order to account for the pattern of results from the first four experiments of the present study across blocked and mixed conditions, however, it must be assumed that some nonconflict probe trials are more or less similar to their prime trials, depending on whether they occur in mixed or pure blocks. This assumption is required because negative priming was observed on nonconflict probe trials in the mixed blocks but not in the pure blocks, when those trials included either nonresponse-letter distractors (Experiment 2) or pound-sign distractors (Experiment 3).

While it may be that stimuli across trials can appear more or less similar depending on the context in which they are presented (see Duncan & Humphreys, 1989, for evidence of this in a within-trial context), the results of Experiment 5 of the present study cannot be accounted for within the memory-retrieval model by assuming that retrieval depends on the similarity between probe trials and their prime trials. Nonconflict probe trials in Experiment 5 consisted of only a single stimulus, whereas prime trials consisted of two. Therefore, in terms of the similarity between nonconflict probe trials and their prime trials, Experiments 5 and 1 were identical. Yet negative priming was observed on nonconflict probe trials in Experiment 5 and not in Experiment 1.

Specific-Process Models

If not for the reasons suggested by any of these models (Houghton & Tipper, 1994; Neill et al., 1992), then why does negative priming often fail to occur when probes can be identified easily as nonconflict? As mentioned in the introduction, it is possible that negative priming is associated with a specific process that only sometimes contributes to reaction time, and that therefore only sometimes allows negative priming to be observed. Within this general framework, there are two ways in which negative priming might fail to occur when probes can be identified easily as nonconflict trials.

First, when it is possible that information is present that could elicit an incorrect response, some process

might be engaged that is not otherwise engaged. If negative priming reflects slowing that is associated specifically with this process, negative priming might be observed only if that process were engaged on the probe trial. Another way of stating this hypothesis is that there are multiple routes along which processing may proceed, and only a subset involves the process that is affected on the prime trial (see, for example, Frith & Done, 1986, for a discussion of multiple-route models of processing). Only if processing on the probe trial follows a route that includes the critical process will negative priming be observed. Which route is followed may be determined by whether there is a danger that conflicting information will elicit an incorrect response.

Second, negative priming may be associated with a specific process that is always engaged, but that only sometimes contributes to reaction time. For example, processing might take the form of a race model or a critical-path model. According to both types of model, there are two (or more) sets of processes by which a response can be elicited. These processes proceed simultaneously. According to race models, which set of processes elicits the response on any given trial is determined by which set of processes is completed first (see, for example, Logan, 1988; Mordkoff & Yantis, 1991; Osman, Kornblum, & Meyer, 1986, for discussions of race models). Therefore, reaction time within a race model is determined by the shortest set of processes. If negative priming were associated with a process that occurs only within a path that is longer than the shortest path, no slowing would be observed within reaction time. In contrast, according to critical-path models, all processes within the network must be completed. Therefore, reaction time is determined by the longest set of processes. Thus, if negative priming were associated with a process that occurred only within a path that is shorter than the longest path, no slowing would be observed within reaction time. (See Schweickert & Wang, 1993, for a method of distinguishing between race and critical-path models.)

For the purposes of the present discussion, the important characteristic that is shared by multiple-route models and models such as race and critical-path models is that negative priming is assumed to be associated with a specific process that only sometimes contributes to reaction time, and that therefore only sometimes allows negative priming to be observed. Assuming that such an account is true, the process with which negative priming is associated remains to be determined.

Negative Priming and Selective Attention

The conditions under which negative priming did and did not occur in the present study suggest that it is associated with a process that is responsible for protecting the system from eliciting a response that is based on incorrect information. Consistent with the idea that such a process would be engaged conservatively, negative priming occurred during all conditions under which it

might have seemed that incorrect information could have elicited a response, namely, (1) when both the distractor and the target were associated with viable responses, and (2) when, although the distractor was not associated with a response, this was difficult to ascertain. Moreover, negative priming failed to occur only when such protection was clearly not necessary, namely when it could be ascertained—either before or quickly following stimulus presentation—that the distractor was not associated with a response.

Tipper and Cranston (1985) have offered a specific example of such a protection process. They suggested that protection against incorrect information eliciting a response occurs through the inhibition of processes that are normally responsible for translating stimulus representations into response codes. This inhibition occurs for distractors, but not for targets. Therefore, responses will tend to be based on targets rather than on distractors. According to their model, the inhibition is maintained as part of the selection process. If selection is unnecessary, and therefore not engaged, the inhibition will decay rapidly, and no negative priming will be observed. In contrast, if selection is necessary, and the inhibition is maintained, the representation of a recently inhibited stimulus may be translated into a response more slowly than would the representation of a new stimulus.

An important implication of the view that negative priming manifests a protection process of the sort described here is that it may manifest a specific aspect of selective attention, rather than selective attention in general. Many conditions that require selective attention do not involve distracting information that directly conflicts with the correct response. For example, consider the task of reading sheet music while playing an instrument. There is a lot of visual information surrounding the musician that does not threaten to elicit a wrong note, but that nonetheless must be selected out. Similarly, in the pure blocks of the present study, the pound-sign, random-dot, and nonresponse-letter distractors did not threaten to elicit an incorrect response, but the targets still had to be selected from among them in order to make the required responses. Thus, perhaps negative priming is a measure of a rather specific aspect of the selection process. The occurrence of negative priming may be taken as an indication that this aspect of selection was engaged; the failure of negative priming to occur may be taken as an indication that this aspect of selection was not engaged.

Finally, if negative priming is associated specifically with a protection process, why did Yee (1991) observe negative priming in experiments in which protection should have been unnecessary? All probes in Yee's experiments were nonconflict trials. The task, however, required "higher" processing than stimulus identification. Moreover, the subjects had to switch tasks between prime and probe trials. It is possible that the relatively difficult processing that was necessary in these experiments caused the process with which negative priming

is associated to be engaged and therefore to contribute to reaction time, despite there being no threat from conflicting information. The results may indicate that negative priming is associated with a protection process that functions more generally than by inhibiting the translation of distractor representations into response codes, or they may indicate that the process is engaged extremely conservatively, and that the difficult processing of Yee's task caused the process to be engaged by default.

Conclusions

The present results provide further evidence that negative priming can fail to occur when there is no conflicting information present on the probe trial. They also indicate that the slowing will only fail to occur when the nonconflict probe trials can be identified easily as non-conflict. It is suggested that negative priming sometimes fails to occur because it is associated with a process that is involved in protecting the system from eliciting a response based on wrong information, and that this process only sometimes contributes to reaction time. A candidate protection process has been described by Tipper and Cranston (1985), whereby distractor representations are prevented from being translated into response codes. Results reported by Yee (1991), however, suggest either that the role of the protection process is more general than this, or that the process is engaged by default when task processing is especially demanding. Additional research is required to identify more specifically the critical process with which negative priming may be associated. An important implication of a specific-process view is that negative priming may manifest a particular aspect of selective attention, rather than selective attention in general, and that it might be used as an indicator that this aspect of selection has been engaged. Where has all the inhibition gone? The answer may be "nowhere"; though it cannot always be observed in reaction time, the inhibition may remain.

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NOTES

1. This three-way interaction was significant in both Experiments 1 and 4. Moreover, greater error rates were observed on ignored-repetition probe trials than on control probe trials in the pure-nonconflict conditions in both Experiments 1 and 4, in which no negative priming was observed in reaction time. It is possible, therefore, that a speed-accuracy trade-off obscured negative priming in these conditions. However, these differences were not statistically reliable. Moreover, negative priming failed to occur in many other conditions in which error rates were not consistent with a speed-accuracy trade-off. It is not clear why these two conditions alone should have caused a speed-accuracy trade-off to obscure effects in this way, while others did not. These differences have therefore been assumed to be noise, though it is possible that they are not.

2. The relative discriminability between conflict and nonconflict trials across Experiments 1-4 was tested in a separate experiment. Twelve subjects identified the displays from each of the experiments reported in this study as either including a distractor from the target set (conflict) or not including a distractor from the target set (nonconflict). As in the original experiments, displays were unmasked and responses were speeded. Identification times were not statistically different for the displays used in Experiments 1 (no-distractor nonconflict trials) and 4 (random-dot nonconflict trials) [466 msec and 474 msec, respectively; $t(11) = 1.18$, $p > .1$]. Displays from Experiment 2 (nonresponse-letter nonconflict trials) were identified more slowly than those of Experiment 3 (pound-sign nonconflict trials) [623 msec and 517 msec, respectively; $t(11) = 7.25$, $p < .005$]. Finally, displays from Experiment 3 (pound-sign nonconflict trials) were identified more slowly than displays from Experiment 1 (no-distractor nonconflict trials) [517 msec and 466 msec, respectively; $t(11) = 3.84$, $p < .025$].

(Manuscript received May 13, 1993;
revision accepted for publication December 23, 1993.)