Memory & Cognition
2000, 28 (8), 1429-1436

Deeper processing at target selection increases the magnitude of negative priming

PENNY L. YEE, KRISTINE E. SANTORO, AMY L. GREY, and VANESSA WOOG
Hamilton College, Clinton, New York

Do deeper levels of processing produce equivalent priming effects at all stages of task performance? In Experiment 1, we varied the level of processing factorially across two task stages—target selection and response selection. Each stage required perceptual (e.g., color) or conceptual (e.g., friendliness) processing of stimulus items (i.e., animal names). Negative priming was substantially greater when deeper processing was required at the *target selection* stage, but it was unaffected by the level of processing at the response selection stage. In contrast, positive priming was greater when deeper processing was required at the *response selection* stage, but it was unaffected by processing at the target selection stage. In Experiment 2, we generalized this finding using a task in which numeric targets were selected on the basis of their parity. As in Experiment 1, the deeper level of processing at the target selection stage produced a larger negative priming effect. These results illuminate the role of target selection demands in modulating the strength of negative priming.

A growing literature has demonstrated robust effects of negative priming. For example, it has been found that information that has recently been intentionally ignored is responded to more slowly when it is encountered again (e.g., Allport, Tipper, & Chmiel, 1985; Neill, 1977; Tipper, 1985; Yee, 1991; see also reviews by Fox, 1995; May, Kane, & Hasher, 1995). For example, if on trial *N* a person must ignore a drawing of a cat, that person's naming of the cat drawing on trial *N* + 1 would be slower than if a new drawing—for example, a guitar (Tipper, 1985)—was to be named. Many researchers agree that negative priming is the cognitive consequence of one's ignoring competing events (e.g., Houghton & Tipper, 1994; Neill & Valdes, 1992; Neill, Valdes, & Terry, 1995; Neill, Valdes, Terry, & Gorfein, 1992). However, recent evidence has put into question whether it is necessary to actively ignore distractors in order to produce negative priming effects (MacDonald, Joordens, & Seergobin, 1999; Milliken & Joordens, 1996; Milliken, Joordens, Merikle, & Seiffert, 1998; Tipper, Weaver, & Milliken, 1995), which has made the link between negative priming and selective attention more ambiguous. Such findings clearly illustrate that the precise mechanisms of negative priming are not fully understood. The present study was designed to discover the extent to which negative priming effects are modulated by the level of processing of stimulus items so that we can better understand the connection between negative priming and selective attentional processes.

Most negative priming studies have required relatively low level processing of the to-be-ignored information. Participants discriminate between targets and distractors on the basis of their physical properties, such as color, size, shape, or location (e.g., Allport, Tipper, & Chmiel, 1985; Neill, 1977; Neill, Lissner, & Beck, 1990; Tipper, 1985; Tipper & Cranston, 1985). Although we frequently direct our actions on the basis of such physical properties, we can also direct our behavior on the basis of conceptual attributes. For example, we can search a car dealer's lot for a white four-door wagon (physical properties) or for a car that has a comfortable ride (conceptual properties). Although studies of priming that have relied on physical properties have led to important findings, they do not fully explain how selection of conceptual properties might occur or, more specifically, whether negative priming effects might be influenced by the kind of processing demands (i.e., physical vs. conceptual) that guide selection. We explored these questions by examining whether level of processing effects on negative priming differ, on the basis of whether processing level is manipulated at the target selection stage or at the response selection stage.

Processing Stages in Selective Attention Tasks

We distinguished between two stages of task performance—target selection and response selection. The term *target selection* refers to the processes used in the identification of a target in a field of irrelevant distractors (i.e., the encoding of a stimulus as the target). The term *response*

These data were previously presented at the Thirty-sixth Annual Meeting of the Psychonomic Society, November, 1995. Portions of this research were supported by an award from the Academic Fund for Seniors at Hamilton College to K.E.S., the Ralph E. Hansmann Science Student Support Fund awarded to A.L.G., the Pew Undergraduate Science Education Program, and the Psychology Department at Hamilton College. We thank Gregory R. Pierce and Jonathan Vaughan for extensive comments on earlier drafts of the manuscript, as well as Kelly DeLuca, Kathleen Cunniff, Teal Crawford, and Kristin Malloy for their assistance with pilot testing and many other aspects in the design of these experiments. Correspondence concerning this article should be addressed to P. L. Yee, Department of Psychology, 198 College Hill Rd., Clinton, NY 13323 (e-mail: pyee@hamilton.edu).

selection refers to the tasks performed once the target has been selected (i.e., the decision rendered about the target). For instance, imagine two words, one in the color red and one in the color blue. The task is to name the red word. Target selection in this case involves the low-level perceptual processes used to focus on the red object. *Response selection* refers to posttarget selection processes that produce articulation of the word in red.

Varying Levels of Processing in Selective Attention Tasks

We varied the depth of semantic analysis at two stages of performance. At the target selection stage, we focused on the process of discriminating between relevant and irrelevant objects. We defined our selection criteria in terms of either perceptual properties or conceptual properties of stimulus items. Perceptual target selection occurs in situations in which the targets are identified by their physical properties (e.g., shape, location, or color). In contrast, conceptual target selection occurs in situations in which targets are identified by their semantic properties (e.g., animacy, friendliness, or function). The latter form of target selection requires greater processing of to-be-ignored objects before filtering of distractors can occur. In order for selection to occur at this level, one must process both the target and the distractor at deeper levels. If negative priming mechanisms are tied to processes involved in filtering relevant from irrelevant information, we should observe levels of processing effects at the target selection stage.

At the response selection stage, we focused on the level of processing required for a task to be performed on the target item. Perceptual response selection occurs in situations in which the participants must report a low-level feature (e.g., color) of the target. Conceptual response selection occurs in situations in which the participants must report a semantic characteristic (e.g., superordinate category or function) of the target that is not directly observable from sensory cues. If negative priming is tied to response selection mechanisms, we should observe levels of processing effects at this stage.

Predictions

The levels of processing hypothesis predicts that deeper levels of processing will produce greater priming effects. This is certainly true for positive priming. Henik, Friedrich, and Kellogg (1983) demonstrated that tasks that require semantic processing (as in naming or lexical decision tasks) generate greater positive priming than do tasks that demand shallower levels of analysis (as in color naming or letter search tasks). The larger priming effect of deeper processing has been attributed to the enhanced activation of codes generated by attentional processing. In order to generalize the Henik et al. result to negative priming, we assumed that the processing received by ignored objects would parallel that received by attended ones (i.e., the richer activation associated with a deeper level of processing of attended items also might create a richer pattern of activation for ignored items). Because greater activation should produce more interference, larger negative priming effects should be observed.

The target selection hypothesis predicts that the levels of processing effects on negative priming will be observed only at the target selection stage (Houghton & Tipper, 1994). Because target selection processes operate when stimulus properties are first being identified, they are more likely to affect the activation of stimulus items. Target and distractor stimuli are processed similarly until the target is selected. Once the target has been selected, the distractor is no longer necessary for responding and, therefore, can be ignored. Thus, this model predicts that the levels of processing manipulations at the target selection stage will have a greater impact on negative priming because it is the pattern of distractor activation that affects the magnitude of negative priming.

The processing congruency hypothesis predicts that when semantic information is relevant for target selection, negative priming will be greater when semantic information is also relevant for response selection. Similarly, when perceptual information is relevant for target selection, negative priming will be larger when perceptual information is also relevant for response selection. Such predictions are analogous to reports that the response demands of a task (i.e., reporting the identity or location of a target) interact with the features of a prime distractor, which produce negative priming on probe trials (Tipper, Weaver, & Houghton, 1994). The processing congruency hypothesis generalizes this effect to the processing that occurs within a prime or probe trial by predicting interactions between response demands and levels of processing at the target selection stage.

EXPERIMENT 1

In Experiment 1, we examined these hypotheses by using tasks in which perceptual and conceptual levels of processing were crossed at the target selection stage and at the response selection stage of performance. At the target selection stage, the targets were to be identified in perceptual terms on the basis of color (i.e., the red word) or in conceptual terms on the basis of perceived actual size (i.e., the bigger animal). At the response selection stage, the participants were to indicate the letter case of the target word (i.e., either upper or lower) or the dangerousness of the named animal (i.e., either safe or harmful). Each of the four conditions (perceptual–perceptual, perceptual–conceptual, conceptual–perceptual, and conceptual–conceptual) represented a unique combination of these manipulations at the two stages of processing. The first part of each condition name refers to the level of processing required at the target selection stage, and the second part of the name refers to the level of processing required for the response stage. For example, the task for the participants in the perceptual–conceptual group was to determine whether the red word named a safe animal.

Method

Participants

Sixty-three male and 81 female undergraduates volunteered for this experiment and were randomly assigned to one of the four task groups: Perceptual–perceptual (12 male, 24 female), perceptual–conceptual (18 male, 18 female), conceptual–perceptual (16 male, 20 female), and conceptual–conceptual (17 male, 19 female). All were native English speakers and had normal color vision. The testing session lasted approximately 20 min, and the participants were each paid $4.00.

Prime–Probe Conditions

In order to assess priming effects, four prime–probe conditions were designed. Each condition was composed of a couplet of trials—a prime trial and a probe trial. In the attend–attend condition, the target word of the prime trial was the target in the probe trial. This condition provided a measure of positive repetition priming. In the ignore–ignore condition, the distractor word of the prime trial was the distractor word in the probe trial. This condition provided a means of assessing the persisting benefits of ignoring the same stimulus on prime and probe trials. In the ignore–attend condition, the distractor word in the prime trial became the target in the probe trial. This was the key condition for measuring negative priming; the response time (RT) in the probe trial revealed the costs associated with having ignored the same item in the prime trial. In the control condition, the target and distractor word pairs were random combinations of the different animal types presented in the prime and probe trials. The constraints are detailed below.

Materials

The stimuli were drawn from a list of names of 36 animals that varied in size (i.e., small, medium, or large) and predacity (i.e., safe or dangerous), as was judged by three independent raters. The conceptual features of size and predacity were crossed to create six categories of names that each had six exemplars—small–safe, small–dangerous, medium–safe, medium–dangerous, large–safe, and large–dangerous. The perceptual features were the color (i.e., red or blue) and letter case (i.e., upper or lower) in which the names were presented. Prime and probe trial couplets were constructed so that paired animal names differed in size, predacity, color, and letter case. These properties were also balanced across targets and distractors.

The decision rule for the conceptual target selection task was based on the size of the animal; that is, the participants were to indicate the larger of the animals. This rule constrained the choice of stimuli for the ignore–attend couplets, because in order for the prime distractor to become the probe target, it had to be the smaller of two animals in the prime trial but the larger of two animals in the probe trial. Only medium-sized animals could serve in this role. Thus, in the ignore–attend condition, the prime pair consisted of a large and a medium animal, and the probe pair consisted of a medium and a small animal. Twelve different stimulus lists rotated through each of the prime–probe conditions. The couplets in each list were presented in different random orders for each participant.

Design

Task group (perceptual–perceptual, perceptual–conceptual, conceptual–perceptual, and conceptual–conceptual) was manipulated between subjects, whereas the four prime–probe conditions (attend–attend, ignore–ignore, ignore–attend, and control) were manipulated within subjects. There were 42 prime–probe couplets presented in each of the attend-attend, ignore-ignore, and control conditions and 18 prime–probe couplets in the ignore–attend condition.

In the perceptual target selection conditions, the target word was presented in red and the distractor in blue. In the conceptual target selection conditions, the colors of the target and the distractor were determined randomly with the constraint that one had to be red and the other blue.

Each target appeared equally often in the top and bottom positions and equally often in the same and different positions across the prime and probe trials. Equal numbers of targets and distractors were in upper and lower case, and equal numbers belonged to the safe and dangerous categories.

Apparatus

Stimulus presentation and response collection were performed on Macintosh IIci computers equipped with color monitors and button boxes and controlled by the PsyScope program (Cohen, MacWhinney, Flatt, & Provost, 1993). All stimulus items were presented in point size 12, Chicago font, and were viewed from a distance of approximately 18 in. The prime and probe displays subtended a visual angle of 3.3° along the vertical axis.

Procedure

The participants completed 20 prime–probe practice trials, followed by four blocks of 36 prime–probe couplets for a total of 72 single trials. The participants were offered breaks between blocks.

Each block began with a 1,000-msec intertrial interval (ITI) followed by a fixation (+) centered on the computer screen for 500 msec. The primes consisted of two words, one above the other, which were displayed until the participant responded. Each response to the prime was followed by a blank screen for 250 msec, a fixation (+) for 500 msec, and then the probe trial. The probes consisted of similar pairs of words, which were displayed until the participant responded. Prime and probe trials were alternated so that the participants were given the impression of an extended series of trials.

Results

Probe RTs for correct responses were analyzed to assess priming effects. First, we describe the overall task effects (a between-subjects analysis) and then examine the negative and positive priming effects (both within-subjects analyses). We defined negative priming in each task group as the difference in probe RTs between the ignore–attend and control conditions. We examined positive priming by making two comparisons; first, we compared the difference in probe RTs between the control and attend–attend conditions and, second, between the control and ignore–ignore conditions. We excluded from our analyses RTs that were greater than three standard deviations from a participant's mean performance within a condition and those responses that followed an incorrect prime trial. Table 1 presents the RT and error data for each task and for the four prime–probe conditions.

Overall Task Effects (Between-Subjects Factors).

Response times. Task type affected overall RTs, as indicated by a 2 × 2 analysis of variance (ANOVA) with target selection task and response selection task as the between-subjects factors. Mean RTs for the conceptual target selection group (1625 msec) were longer than those for the perceptual target selection group (721 msec) [$F(1,140) = 284.28, MS_e = 413{,}642.98, p < .001$]. Mean RTs for the perceptual response selection task (1,186 msec) did not differ from those for the conceptual response selection task (1,160 msec) [$F(1,140) = 0.25, MS_e = 413{,}642.98, p > .60$]. A significant interaction be-

Table 1
Mean Probe Response Times (RTs, in Milliseconds) and Percentage of Errors in Experiment 1

	Prime–Probe Conditions				
Group	Attend–Attend	Ignore–Ignore	Ignore–Attend	Control	*M*
Perceptual–perceptual					
RT	641	628	669	634	643
SD	140	116	196	131	
Priming effect	−7	+6	−35*		
% E	6.9	7.1	5.6	7.1	6.7
SD	6.1	5.8	6.6	5.0	
Perceptual–conceptual					
RT	710	809	860	819	800
SD	161	164	213	172	
Priming effect	+109**	+10	−41*		
% E	1.4	7.9	9.4	5.3	6.0
SD	1.8	5.6	7.6	4.8	
Conceptual–perceptual					
RT	1,674	1,705	1,862	1,676	1,729
SD	459	460	636	405	
Priming effect	+2	−29	−186**		
% E	8.8	6.7	8.4	6.8	7.7
SD	5.6	5.5	8.6	5.0	
Conceptual–conceptual					
RT	1,400	1,481	1,664	1,535	1,520
SD	364	409	454	406	
Priming effect	+135**	+54	−129**		
% E	11.1	12.6	14.1	13.3	12.8
SD	8.8	7.1	12.4	8.9	
Mean RT	1,106	1,156	1,264	1,166	
Mean %	7.0	8.6	9.4	8.1	

$*p < .01$. $**p < .001$.

tween target selection and response selection was observed [$F(1,140) = 11.63$, $MS_e = 413{,}542.98$, $p < .001$]. Post hoc analyses indicated that, within the target selection condition, RTs were faster when the same level of processing was required for both target selection and response selection.

Errors. Error data were analyzed in the same manner as were RTs. Both main effects were significant. The participants made fewer errors in the perceptual target selection condition [$F(1,140) = 18.71$, $MS_e = 116.21$, $p < .001$] and in the perceptual response condition [$F(1,140) = 6.02$, $MS_e = 116.21$, $p < .05$] than in the conceptual level conditions. A significant interaction indicates that the participants made significantly more errors in the conceptual–conceptual task than in the other three tasks [$F(1,140) = 10.32$, $MS_e = 116.21$, $p < .005$].

Negative Priming Effects: The Ignore–Attend Condition Versus Control

Negative and positive priming effects were analyzed with 2 × 2 × 2 ANOVAs with target selection task and response selection task as the between-subjects factors and prime-probe condition as the within-subjects factor. Negative priming was evaluated by comparing the ignore–attend condition with the control prime–probe condition. The occurrence of negative priming effects is reflected in the significant main effect of prime–probe condition. Across task group, mean performance in the ignore–attend condition was 98 msec slower than in the control condition [$F(1,140) = 30.29$, $MS_e = 22{,}761.36$, $p < .001$]. This effect was still significant after controlling for stimulus type and prime– probe response compatibility [$F(1,140) = 6.38$, $MS_e = 52{,}163.43$, $p < .05$]. Negative priming in the conceptual target selection task (−157 msec) was significantly larger than in the perceptual target selection task (−38 msec) [$F(1,140) = 11.23$, $MS_e = 22{,}761.36$, $p < .001$]. There was no significant interaction between negative priming and the response selection factor [$F(1,140) = 0.53$, $MS_e = 22{,}761.36$, $p > .45$].

Positive Priming Effects

Attend–attend condition versus control condition. A significant main effect of prime-probe condition indicated the occurrence of positive priming [$F(1,140) = 22.75$, $MS_e = 11{,}248.24$, $p < .001$]. Overall performance in the attend–attend condition was 60 msec faster than that in the control condition. Subsequent analyses revealed a significant interaction between positive priming and response selection—that is, positive priming was significantly larger for the conceptual response selection group ($M = +122$ msec, $SD = 170$) than for the perceptual target selection group ($M = -2$ msec, $SD = 125$) [$F(1,140) =$

25.03, $MS_e = 11{,}248.24$, $p < .001$]. The target selection factor did not interact with positive priming [$F(1,140) = 0.52$, $MS_e = 11{,}248.24$, $p > .45$].

Ignore–ignore condition versus control condition. Mean RTs in the ignore-ignore condition (1,156 msec) were somewhat faster than those in the control condition (1,166 msec), but this difference was not significant [$F(1,140) = 0.53$, $MS_e = 13{,}806.59$, $p > .45$]. There were no significant interactions with response selection [$F(1,140) = 2.53$, $MS_e = 13{,}806.59$, $p > .10$] or target selection [$F(1,140) = 0.04$, $MS_e = 13{,}806.59$, $p > .80$].

Errors in Prime–Probe Conditions

Significantly fewer errors were observed with the attend–attend couplets compared with the other couplets [$F(1,140) = 5.40$, $MS_e = 25.87$, $p < .005$]. (See Table 1.) Performance in the other conditions did not differ from each other.

Discussion

Current models of negative priming effects suggest that negative priming is related to the degree of activation in memory (Houghton & Tipper, 1994; Malley & Strayer, 1995). We reasoned that larger negative priming effects would occur when deeper processing had to be performed. Consistent with this prediction, negative priming effects were considerably larger when the participants based their target selection on conceptual information. Levels of processing manipulations at the response selection stage did not affect the magnitude of negative priming. Thus, the data favor the target selection hypothesis and suggest that the processes underlying target selection are more closely linked to negative priming than those that underlie response selection.

Whereas target selection was shown to affect negative priming, response selection was shown to affect positive priming. When the participants focused on the same word in both the prime and the probe trials (the attend–attend condition), deeper levels of processing at the response selection stage produced significantly greater positive priming effects than when the participants focused on a novel target. A shallow level of processing at the response selection stage produced negligible positive priming.

The observed relation between negative priming and target selection, on one hand, and that between positive priming and response selection, on the other, is indicative of a double dissociation between stage of processing and type of priming. The pattern that we observed suggests a strong connection between negative priming mechanisms and the processes that direct attention to target stimuli, and between positive priming mechanisms and later-occurring response selection processes. The latter observation is consistent with findings of postselection positive priming effects in lexical decision tasks (Koriat, 1981). The combined results, however, conflict with theories that explain negative and positive priming effects in terms of prime–probe similarity (Neill, 1997; Neill & Kahan, 1999). Neill (1997) proposed that priming effects are based on one's retrieval of recent memories about how one has dealt with similar stimuli in the past. Our data suggest that priming might also be a reflection of the effects of other cognitive (i.e., attentional) processes.

EXPERIMENT 2

In Experiment 1, the conceptual target selection task required a mental comparison of two named animals. Experiment 2 was designed to replicate the levels of processing effects observed in Experiment 1 by using a task that did not require a direct comparison between targets and distractors. We changed the stimulus set to numbers; in the conceptual target selection condition the participants were to select targets on the basis of a number's parity (i.e., odd or even). Because the manipulation at response selection stages had not affected the magnitude of negative priming in Experiment 1, it was omitted. All response selection tasks required conceptual level analysis of the target (i.e., determining whether a number was divisible by 3). We predicted that negative priming effects would be larger when target selection was based on parity than when it was based on color.

The participants were presented with a pair of numbers on each trial—one red, one blue, one odd, and one even. In the conceptual target selection condition, the participants were to choose the target on the basis of whether it was odd or even. In the perceptual target selection condition, the participants were to choose the target on the basis of its color.

Method

Participants

Twenty-two male and 18 female students participated in the study. All were native English speakers and had normal or corrected-to-normal vision. They were tested individually for approximately 30 min, and each was paid $4.00.

Materials

The stimulus materials were eight numbers that fell into the following four categories: (1) odd and a multiple of 3 (3 and 9), (2) odd and not a multiple of 3 (7 and 11), (3) even and a multiple of 3 (6 and 12), and (4) even and not a multiple of 3 (4 and 8). Odd and even numbers were randomly paired in such a way that each number appeared equally often. The stimulus list consisted of 32 prime–probe couplets in each of four prime–probe conditions.

The numbers were presented in either red or blue and in bold or outline face so that they would parallel the multiple feature characteristics in Experiment 1. These traits were orthogonally paired in each trial. The numbers were presented in the upper or lower half of the screen in Chicago font with point size 12. The participants viewed the display from a distance of approximately 18 in. The visual angle from center fixation to the nearest edge of the numeric display (whether in the upper or lower half of the screen) was 2°. The visual angle from fixation to the outer edge of the display was 4.5°.

Apparatus

The equipment and testing set-up were identical to those in Experiment 1.

Design

This study used a 2 (target selection rule) × 4 (prime–probe condition) mixed factorial design. The participants were randomly assigned to either the perceptual or the conceptual target selection group. The four prime–probe conditions were the same as those in Experiment 1.

The location of the stimulus pair (above or below central fixation) indicated to the participants which number to select (either odd or even for conceptual conditions; either blue or red for perceptual conditions). Stimulus location was determined randomly with the following constraints. (1) In order for the target to be repeated in the attend–attend couplets (or the distractor in the ignore–ignore couplets), number pairs were presented in the same location within a couplet (i.e., in both displays either above or below fixation). (2) In order for ignored distractors in the prime trial to become targets in the probe trial of ignore–attend couplets, a switch in the locations of stimuli between the prime and probe trials was necessary. The locations of half the couplets in the control trial were switched in the prime and probe trials so that appropriate comparisons with different prime–probe conditions could be made.

Procedure

Trials began with a 500-msec presentation of a fixation (+) at the center of the screen, followed by presentation of the prime (i.e., a pair of numbers, one directly above the other) that lasted until the participant responded. After a 500-msec delay, the sequence was repeated for the probe trial. The sequence of the prime and probe trials was alternated. After four practice blocks of 32 prime–probe couplets each, the participants completed four test blocks. The extensive practice ensured that the participants were confident with the task and the selection rules. The participants were given breaks following each block of trials.

Results and Discussion

Analyses were conducted using the same general procedure as that in Experiment 1.

Negative Priming Effects

Table 2 presents a summary of RT and accuracy data in the ignore–attend and switch control conditions. A 2 × 2 ANOVA was performed with target selection (perceptual vs. conceptual) as the between-subjects factor and prime–probe condition (ignore–attend vs. switch control) as the within-subjects factor. Both main effects were significant. Responses in the conceptual target selection condition were slower than in the perceptual target selection condition [$F(1,38) = 58.80$, $MS_e = 160{,}902.45$, $p < .001$]. Responses in the ignore–attend condition were slower than in the switch control condition [$F(1,38) = 10.69$, $MS_e = 14{,}644.06$, $p < .005$]. Negative priming effects were significantly larger in the conceptual target selection task than in the perceptual target selection task [$F(1,38) = 8.04$, $MS_e = 14{,}644.06$, $p < .01$].

Table 2
Mean Response Times (RTs, in Milliseconds) and Percentage of Errors for Ignore–Attend and Control Conditions in Experiment 2

	Prime–Probe Conditions		
Group	Ignore–Attend	Switch Control	*M*
Perceptual			
RT	653	645	649
SD	83	90	
Priming effect	−8		
% E	6.2	4.0	5.1
SD	6.4	8.6	
Conceptual			
RT	1,194	1,078	1,136
SD	329	260	
Priming effect	−116*		
% E	3.1	6.2	4.6
SD	5.7	10.2	
Mean RT	924	862	
Mean %	4.6	5.1	

*$p < .001$.

An analysis of errors revealed no main effects. There was a significant interaction between target selection and prime–probe condition [$F(1,38) = 5.48$, $MS_e = 50.30$, $p < .05$]; however, post hoc pairwise analyses did not reveal reliable differences between any of the cell means ($p > .05$).

Positive Priming Effects

Positive priming effects were evaluated in a 2 × 3 ANOVA with target selection as the between-subjects factor and prime–probe condition as the within-subjects factor (attend–attend vs. ignore–ignore vs. nonswitch control). Table 3 presents a summary of results in these conditions. Responses in the perceptual target selection task were significantly faster than those in the conceptual target selection task [$F(1,38) = 38.526$, $MS_e = 86{,}469.23$, $p < .001$]. No significant priming effects were observed in the prime–probe conditions [$F(1,38) = 1.22$, $MS_e = 7{,}603.75$, $p > .30$], and there was no interaction between target selection and prime–probe conditions [$F(1,38) = 1.86$, $p > .16$]. An analysis of errors revealed no significant effects.

GENERAL DISCUSSION

Our finding that deeper processing produces greater negative priming is consistent with reports by Milliken and his colleagues (Milliken & Joordens, 1996; Milliken et al., 1998) that explicit ignoring might not be necessary for negative priming to occur. In the conceptual target selection conditions, the prime distractor was processed quite extensively. Deeper processing at the target selection stage delays decisions of whether or not to ignore a distractor until sufficient information has accumulated to reject it. Distractors were ignored during deeper processing, but not to the same extent as distractors were during shallower processing conditions. These observations raise questions about whether the enhanced negative priming effects are due to delays in active ignoring, to level of processing, or to other retroactive memorial processes (described below).

The overall pattern of results is most consistent with the target selection hypothesis, which is based on a distractor inhibition model of negative priming (e.g., Houghton & Tipper, 1994; Houghton, Tipper, Weaver, & Shore, 1996). According to this model, negative priming arises from the active inhibition of processing of ignored in-

Table 3
Mean Response Times (RTs, in Milliseconds) and Percentage of Errors for Attend–Attend and Ignore–Ignore Conditions in Experiment 2

	Prime–Probe Conditions			
Group	Attend–Attend	Ignore–Ignore	Nonswitch Control	*M*
Perceptual				
RT	559	627	598	595
SD	49	96	88	
Priming effect	+39	−29		
% E	4.6	3.8	1.8	3.4
SD	4.6	4.7	4.3	
Conceptual				
RT	934	927	923	928
SD	228	242	271	
Priming effect	−11	−4		
% E	2.2	1.0	2.9	2.0
SD	2.0	2.3	6.3	
Mean RT	746	777	761	
Mean %	3.4	2.4	2.4	

formation. Persistent inhibition causes delays in the processing of an object that has recently been ignored. The amount of inhibition generated depends on the degree of initial activation attained by the distractor. Because higher levels of distractor activation would produce greater interference in target processing, they would require more inhibition and thus would produce larger negative priming effects. This model also predicts that manipulations at the response selection stage will have minimal effects on negative priming, because response selection processes should not affect distractor activation. This prediction is consistent with our observations in Experiment 1.

Whereas variations in the level of processing at the target selection stage influenced the degree of negative priming, variations at the response selection stage affected positive priming. These results challenge recent assertions that positive and negative priming are driven by memory retrieval mechanisms (Neill & Kahan, 1999). According to episodic retrieval theory, probe processing triggers the retrieval of how one has dealt with a previously presented stimulus item that possesses similar characteristics. Greater similarity increases the probability of episodic retrieval (Neill, 1997). When the retrieved information about the processing of the previously presented prime conflicts with the response demands of the probe task, negative priming occurs. When the information is consistent with the probe task demands, positive priming occurs. Although our data cannot address the effects of similarity between prime and probe trials on negative priming, the dissociative effects that we observed suggest that priming effects may also be influenced by other cognitive processes.

Our results argue for the importance of considering stimulus encoding operations in studying negative priming effects. These views are shared, in part, by recent revisions to the episodic retrieval theory of positive and negative priming effects (Neill & Kahan, 1999; Neill & Mathis, 1998). In these revisions, Neill and his colleagues proposed that transfer appropriate/inappropriate processing plays a role in priming effects. Information that is encoded during prime processing will enhance (transfer appropriate processing) or interfere (transfer inappropriate processing) with probe processing, depending on its relevance to the probe target.

Temporal discrimination theory (Milliken et al., 1998) proposes that an interaction between the processing required at encoding and the processing required at retrieval produces negative priming effects. According to this model, negative priming arises from a memorially based discrimination process in which one either retrieves behavioral responses from similar past experiences, or, if past experiences are inappropriate, computes behavioral responses anew from perceptual input. Two processes are involved—an orienting process and a retrieval process. The orienting process determines whether the current probe target is novel (i.e., "new," or whether it is similar to a previous stimulus (i.e., "old"). If it is judged to be new, a new and appropriate response is rapidly computed. In this framework, control trials, which by definition consist of only novel items, have a processing advantage because responses can be computed rapidly since they are unencumbered by retrieval operations. If the stimulus is judged to be old, the retrieval process is triggered and the previously executed response to the old stimulus is automatically retrieved from memory, and, thus, facilitates responding in attended repetition conditions. In typical negative priming conditions, a probe target is related to the previous prime distractor; the retrieval of previous responses prevents probe targets from being quickly classified as new and, at the same time, provides insufficient information for generating the correct response. Because a response is retrieved, the discrimination process is impeded by the attempt to determine whether a new response is to be computed. Thus, negative priming effects arise from the combination of a thwarted discrimination process of categorizing the probe target as new and from a novelty bias in control trials; it does not necessarily arise from the explicit ignoring of the prime distractor. Indeed, Wood and Milliken (1998) reported negative priming effects when primes were actually studied by the participants. They proposed that negative priming occurs because of the dramatic mismatch between the processing demands of the prime tasks and those of the probe tasks.

According to this framework, deep processing at the target selection stage might have increased negative priming effects in two ways. First, negative priming might have been affected by enhancing the apparent novelty of a control stimulus, obviating a memory search. Second, negative priming effects might have been enhanced by more serious impediment in the discrimination process. Deeper processing at the target selection stage necessitates greater levels of attention to the prime distractor. Higher levels of attention might have generated a stronger memorial episode and facilitated retrieval. As a result, classification, at the discrimination stage, of the probe target as new might have been further delayed.

The episodic retrieval and temporal discrimination explanations share the view that retrospective memorial processes influence priming; in memorial processes, the processing outcomes between prime and probe trials are compared. But, the dissociation between type of priming and stage of selection effects that we observed suggests that negative and positive priming might also be influenced by the types of cognitive processes involved in the encoding and selection of targets and responses. These views are not incompatible, since both the attention directed toward a stimulus and how it is responded to will influence its memorial representation.

In summary, the literature suggests that many factors may affect the magnitude of negative priming. Our results indicate that one of these might be the depth of processing at the target selection stage. At the very least, these findings are consistent with the evolving view that encoding processes play an important role in modulating negative priming effects.

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 XI* (pp. 107-132). Hillsdale, NJ: Erlbaum.

Cohen, J., MacWhinney, B., Flatt, M., & Provost, J. (1993). Psyscope: An interactive graphical system for designing and controlling experiments in the psychology laboratory using Macintosh computers. *Behavior Research Methods, Instruments, & Computers*, **25**, 257-271.

Fox, E. (1995) Negative priming from ignored distractors in visual selection: A review. *Psychonomic Bulletin & Review*, **2**, 145-173.

Henik, A., Friedrich, F. J., & Kellogg, W. A. (1983). The dependence of semantic relatedness effects upon prime processing. *Memory & Cognition*, **11**, 366-373.

Houghton, G., & Tipper, S. P. (1994). A model of inhibitory mechanisms in selective attention. In D. Dagenbach & T. H. Carr (Eds.), *Inhibitory processes in attention, memory, and language* (pp. 53-112). San Diego: Academic Press.

Houghton, G., Tipper, S. P., Weaver, B., & Shore, D. I. (1996). Inhibition and interference in selective attention: Some tests of a neural network model. *Visual Cognition*, **3**, 119-164.

Koriat, A. (1981). Semantic facilitation in lexical decision as a function of prime-target association. *Memory & Cognition*, **9**, 587-598.

MacDonald, P. A., Joordens, S., & Seergobin, K. N. (1999). Negative priming effects that are bigger than a breadbox: Attention to distractors does not eliminate negative priming, it enhances it. *Memory & Cognition*, **27**, 197-207.

Malley, G. B., & Strayer, D. L. (1995). Effect of stimulus repetition on positive and negative identity priming. *Perception & Psychophysics*, **57**, 657-667.

May, C. P., Kane, M. J., & Hasher L. (1995). Determinants of negative priming. *Psychological Bulletin*, **118**, 35-54.

Milliken, B., & Joordens, S. (1996). Negative priming without overt prime selection. *Canadian Journal of Experimental Psychology*, **50**, 333-346.

Milliken, B., Joordens, S., Merikle, P., & Seiffert, A. (1998). Selective attention: A re-evaluation of the implications of negative priming. *Psychological Review*, **105**, 203-229.

Neill, W. T. (1977). Inhibitory and facilitatory processes in selective attention. *Journal of Experimental Psychology: Human Perception & Performance*, **3**, 444-450.

Neill, W. T. (1997). Episodic retrieval in negative priming and repetition priming. *Journal of Experimental Psychology: Learning, Memory, & Cognition*, **23**, 1291-1305.

Neill, W. T., & Kahan, T. A. (1999). Response conflict reverses priming: A replication. *Psychonomic Bulletin & Review*, **6**, 304-308.

Neill, W. T., Lissner, L. S., & Beck, J. L. (1990). Negative priming in *same–different* matching: Further evidence for a central locus of inhibition. *Perception & Psychophysics*, **48**, 398-400.

Neill, W. T., & Mathis, K. M. (1998). Transfer-inappropriate processing: Negative priming and related phenomena. In D. L. Medin (Ed.), *The psychology of learning and motivation: Advances in research and theory* (Vol. 38, pp. 1-44). San Diego: Academic Press.

Neill, W. T., & Valdes, L. A. (1992). Persistence of negative priming: Steady state or decay? *Journal of Experimental Psychology: Learning, Memory, & Cognition*, **18**, 565-576.

Neill, W. T., Valdes, L. A., & Terry, K. M. (1995). Selective attention and the inhibitory control of attention. In F. N. Dempster & C. J. Brainerd (Eds.), *Interference and inhibition in cognition* (pp. 207-261). San Diego: Academic Press.

Neill, W. T., Valdes, L. A., Terry, K. M., & Gorfein, D. S. (1992). Persistence of negative priming: II. Evidence for episodic trace retrieval. *Journal of Experimental Psychology: Learning, Memory, & Cognition*, **18**, 993-1000.

Tipper, S. P. (1985). The negative priming effect: Inhibitory priming by ignored objects. *Quarterly Journal of Experimental Psychology*, **37A**, 571-590.

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., Weaver, B., & Houghton, G. (1994). Behavioral goals determine inhibitory mechanisms of selective attention. *Quarterly Journal of Experimental Psychology*, **47A**, 809-840.

Tipper, S. P., Weaver, B., & Milliken, B. (1995). Spatial negative priming without mismatching: Comment on Part and Kanwisher (1994). *Journal of Experimental Psychology: Human Perception & Performance*, **21**, 1220-1229.

Wood, T. J., & Milliken, B. (1998). Negative priming without ignoring. *Psychonomic Bulletin & Review*, **5**, 470-475.

Yee, P. L. (1991). Semantic inhibition of ignored words during a figure classification task. *Quarterly Journal of Experimental Psychology*, **43A**, 127-153.

(Manuscript received August 25, 1997;
revision accepted for publication May 12, 2000.)