Determinants of Negative Priming

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Abstract:

The negative priming task is widely used to investigate attentional inhibition. A critical review of the negative priming literature considers various parameters of the task (e.g., time course, relation to interference, level of occurrence, and susceptibility to changes in task context). It also takes into account life span data and the performance of patients diagnosed with schizophrenia. On these bases, the review suggests that negative priming can be produced by 2 mechanisms: memorial and inhibitory. With respect to inhibition, the review suggests that (a) there are 2 systems, one responsible for identity and the other for location information; and (b) inhibition is a flexible, postselection process operating to prevent recently rejected information from quickly regaining access to effectors, thus helping to establish coherence among selected thought and action streams.

Article:

Allowing distracting information to capture one's attention can be dangerous, irritating, or pleasurable. Consider, for example, the annoyance caused by needing to reread the same passage several times because your thoughts were entirely directed inward while your eye movements were directed at the page. Or consider the pleasure caused by an engaging fantasy during a faculty meeting. Or the danger of that same fantasy when driving in traffic. Distraction can also have intellectually satisfying results if, for example, a new solution to a nagging problem occurs as a result of the particular information being considered in the irrelevant perceptual or thought stream (see Weisberg, 1993). Not surprisingly then, interest in the basic issues of attention and distraction and in their determinants and consequences has had a long history in psychology (e.g., James, 1890; Pillsbury, 1908) that ranges across cognition, personality, and psychopathology.

One recent line of work within cognition that addresses the problems of distraction stems from attention models that assume that all familiar stimuli in the environment activate their representations in memory automatically and in parallel. This vast network of activation then requires the active tempering of all but the most goal-relevant representations for coherent thought and behavior to emerge. Such theories assume that inhibition operates in the service of short- and long-range goals to slow or prevent the conduction of activated but irrelevant representations to effectors including thought, speech, and action (e.g., Navon, 1989a, 1989b; O. Neumann, 1987; Norman & Shallice, 1986). These models became particularly interesting within mainstream cognition as criticisms of another major family of attention models—those that assume general limited capacity—became increasingly frequent and compelling (e.g., O. Neumann, 1987). They have also become particularly interesting in cognition as models attempt to interrelate basic attentional processes to working memory, retrieval, reading, speech comprehension, and speech production (e.g., Gemsbacher, 1990; Hasher & Zacks, 1988). A further source of interest stems from the potential usefulness of such models in the understanding of cognitive development, aging, and aspects of psychopathology (e.g., Dempster, 1992; Frith, 1979; Hasher & Zacks, 1988) .

Central to the value of inhibitory control models of attention is the ability to measure the mechanism that enables suppression of activated but non-goal-relevant representations. Al-though a number of potential methods have been identified as candidates (Posner & Mitchell, 1967; Schvaneveldt, Meyer, & Becker, 1976;

Treisman, 1964; Warren, 1974), the task that is viewed as the most direct index is a selective attention task that yields the *negative priming* effect (for early demonstrations, see Dalrymple-Alford & Budayr, 1966; Greenwald, 1972; Neill, 1977; Tipper, 1985). This effect is seen in the context of tasks in which, across many trials, the participant selects a target (using a cue such as color, location, or appearance) and responds to the identity of that stimulus in the presence of one or more distractors.' The critical manipulation in such a task occurs between consecutive trials: The participant must respond to a target on the current trial (called the *test* trial) that had appeared as a distractor on the previous trial (called the *prime* trial). Response time and accuracy on experimental trials, in which the current target was the previous distractor, are com-pared with response time and accuracy on control trials, in which neither targets nor distractors repeat across trials. (The two types of trials are illustrated in Figure 1.) The negative priming effect is a slowdown in response time (and often, an increase in errors) on experimental as compared with control trials.

The major explanation of the negative priming effect is that some time during or shortly after target selection on the prime trial, the activated representation of the distractor is suppressed or decoupled from potential effectors (Dalrymple-Alford & Budayr, 1966; Neill, 1977; E. Neumann & DeSchepper, 1991; Tipper & Cranston, 1985). If the previous distractor becomes the target on the next test trial, the suppression accorded it on the prime trial then takes some time to dissipate, slowing the response to the target. On this basis, the negative priming effect is widely seen as an index of the basic inhibitory process posited by several contemporary models of attention.

It is not surprising then that the negative priming task itself has come under intense empirical examination. To a large degree, investigations reveal the generality of negative priming (see Appendix). The effect has been demonstrated with a range of stimuli including pictures, words, letters, and Stroop (1935) color words. It has been demonstrated using a range of response tasks including naming the target, making lexical decisions to the target, and classifying the target. It is seen with both manual and spoken responses. It occurs on tasks using a relatively small number of test trials (e.g., 34 trials; Tipper, 1985) and continues to occur across considerable levels of practice (e.g., 1,000+ trials; Tipper, Eissenberg, & Weaver, 1992). Although the methodological and procedural variations suggest the generality of the effect, they also create difficulties in comparing across studies, a process important to any attempt to understand the underlying inhibitory mechanism.

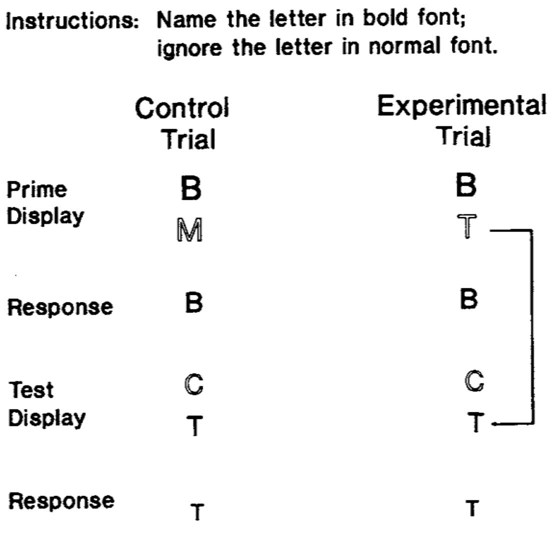

Figure 1. Example trial for identity negative priming task. Negative priming is the difference (in response time or accuracy) between test responses for control versus experimental trials.

The diverse procedures also make it difficult to compare patterns of performance across a broad range of groups, with some showing negative priming and others not. Our goal here is to understand the underlying mechanism of inhibition and to this end, we provide a review of the literature on the negative priming effect, delineating its parameters and boundary conditions. As well, and because there is an alternative to the inhibition explanation of negative priming, our second goal is to evaluate the validity of competing explanations for negative priming. Because the major competing explanation for negative priming is a noninhibitory one, the resolution of this controversy is critical to the larger theoretical impetus behind current interest in the negative priming effect.[2]

With respect to our second goal and to provide a preview, our analysis of the empirical literature in conjunction with several recent findings from our laboratory suggests that the negative priming effect can be produced by two mechanisms, one inhibitory and one memorial. We review the conditions under which each process is likely to operate, and in so doing, we suggest some limits to the use of negative priming as a pure index of inhibition.

Overview

The article is organized into two main parts. The first part is a literature review in which we delineate the parameters of negative priming. The second part addresses competing explanations for negative priming. The literature review discusses four critical issues, the first of which concerns the function of inhibition. To this end, we examine evidence regarding both the time course of negative priming and the relation between negative priming and interference from distractors. It has been commonly held that inhibition aids current selection by denying irrelevant, activated memory representations immediate access to response (e.g., Tipper & Cranston, 1985). Alternatively, inhibition may also, or instead, operate *after* selection to pre-vent information already tagged as irrelevant from becoming reactivated and gaining access to response effectors (Stoltzfus, Hasher, Zacks, Ulivi, & Goldstein, 1993; Tipper, Weaver, Cameron, Brehaut, & Bastedo, 1991). In fact, the evidence suggests that inhibition of identity information may be a postselection mechanism that functions to dampen recently activated irrelevant information.

The second critical issue addressed in the literature review concerns the locus, or level (peripheral features vs. central representations), at which negative priming occurs. We consider whether inhibition dampens only specific perceptual features or response types by examining changes in negative priming associated with shifts in stimuli or response requirements across prime and test trials. The data indicate that negative priming occurs across items that are semantically related but perceptually distinct and across different response modes, thus suggesting that inhibition operates at a central rather than a peripheral level.

The third issue concerns findings of diminished negative priming in several populations, including older adults and patients with schizophrenia, who also demonstrate specific impairments in cognitive functioning that may be rooted in deficiencies of attentional inhibition (e.g., Frith, 1979; Hasher & Zacks, 1988). Negative priming has been used as an index of inhibitory efficiency with these groups, and the mounting evidence for its absence in these populations has been taken as strong support for inhibitory deficit hypotheses. Recent data (Connelly & Hasher, 1993; Sullivan & Faust, 1993), however, suggest that at least for older adults, negative priming may indeed be observed under certain experimental conditions. These instances of negative priming preservation suggest (a) that not all inhibitory mechanisms are uniformly impaired with aging and (b) that spatial and identity systems have independent inhibitory processes.

The fourth and final section of the literature review deals with the impact of experimental context and participant dispositions on the negative priming effect. The data reviewed here indicate that inhibition is a relatively flexible and adaptive process, influenced by both changes in experimental context and participants' strategies.

After reviewing the negative priming literature, we turn to an evaluation of competing explanations for negative priming and the evidence relevant to each. New data from our laboratory, together with existing evidence, strongly suggest that negative priming is the consequence of inhibition under certain methodological conditions and of alternate, memory-based sources un-der others. We begin to delineate the contexts in which memory-based sources may operate.

Review of the Negative Priming Literature

Function of Inhibition

One widely held assumption regarding attentional inhibition is that it operates *during* selection to reduce interference from currently irrelevant items (e.g., Neill, 1977; Neill & Westberry, 1987; Tipper, 1985; Tipper & Baylis, 1987). If inhibition aids current selection, negative priming should be evident immediately after selection and should gradually dissipate once selection is achieved on a given trial. As well, if inhibition functions during selection, negative priming and interference should vary inversely; the more effective suppression is, the less interference there will be.

An alternative view is that inhibition functions *after* selection to prevent information classified as irrelevant from quickly be-coming reactivated, thus giving the selected information the opportunity to become fully organized and integrated with other selected information (Stoltzfus et al., 1993; Tipper, Weaver, Cameron, et al., 1991). If inhibition develops only as selection is being completed, its effects may not be detectable immediately after selection, and it is likely to persist for some time to keep rejected information from effectors. By this view, negative priming will not necessarily vary consistently with interference.

To preview, data from studies exploring the time course of the negative priming effect, as well as the relation between negative priming and interference, suggest that the mechanism responsible for negative priming occurs after selection is complete:

Negative priming requires time to develop, it persists during the processing of other stimuli, and it persists over time. Further-more, a comprehensive examination of the relation between negative priming and interference indicates that the two measures do not consistently covary: Some studies report an inverse relation between negative priming and interference, some indicate a direct relation, and others demonstrate no relation at all. We now consider the data.

Time Course of Negative Priming

Onset of negative priming. The onset of negative priming can be seen in studies that manipulate the delay between prime and test trials. This can be done in two ways: (a) by varying the time between the offset of the prime display and the onset of the test display (the interstimulus interval [ISI]) or (b) by varying the time between a response to the prime display and the presentation of the test display (the response-to-stimulus interval [RSI]) . The results across these time parameters are similar and so are presented together. At the shortest delays (i.e., 20- 50 ms) between prime and test displays, participants naming Stroop color words showed little or no negative priming (Lowe, 1985; Neill & Westberry, 1987), suggesting that inhibition requires some time to accrue. Similar findings were obtained with manipulations of response instructions: When participants were instructed to sacrifice accuracy and respond as rapidly as possible, so as to effectively shorten the time between prime and test, they showed either a lack of negative priming (Neill, 1979; Neill & Westberry, 1987) or facilitation (Neill, 1977; E. Neumann & DeSchepper; 1992) in both reaction time and error rate measures.

Together, these findings suggest that if inhibition underlies negative priming, it develops after selection: Were inhibition operating during target selection or response output on the prime trial, negative priming would be robust immediately following the prime trial (for a similar view, see Fox, in press). Contrary to these expectations, however, negative priming effects are not evident when the time between prime and test displays is limited, whether this limitation results from shortened prime-test delays or from instructions to speed responding. These findings thus suggest that inhibition does not facilitate current selection, opening up the possibility that it operates at some point after selection is made.

Persistence of negative priming. As an alternative to the selection function, inhibition may serve to block selected-against information from immediate reactivation, response effectors, or both. Thus, its function would be to facilitate on-line processing of target information by maintaining the distinction between distracting and goal-relevant information, once that distinction has been established (Stoltzfus et al., 1993; Tipper, Weaver, Cameron, et al., 1991). By this view, inhibition should have relatively long-term effects, persisting both during the processing of new information, at least if that information is consistent with current goals, and over time. By contrast, if inhibition functions to aid in concurrent selection, its potency should dissipate soon after a response is made.

With respect to the impact of intervening events on negative priming, the data are straightforward: Negative priming effects persist despite the intrusion of an event between prime and test trials (DeSchepper & Treisman, 1991; Tipper, Weaver, Cameron, et al., 1991, Experiment 2A). For example, participants naming pictures demonstrated reliable negative priming de-spite having to identify a geometric shape between prime and test trials (Tipper, Weaver, Cameron, et al., 1991, Experiment 2B). Negative priming endures over at least one and, possibly, several intervening trials (DeSchepper & Treisman, 1991), pro-vided that those intervening trials do not require a response to the ignored stimulus (Tipper, Weaver, Cameron, et al., 1991). Thus, if negative priming is produced by inhibition, then these data demonstrate that inhibition is not disrupted by the presentation of new information (at least in limited amounts) but continues to dampen previously irrelevant items during the processing of subsequent information.

Given that negative priming endures across events that impose additional processing demands, one might also expect that it would persist over a delay in time when no further processing demands are made. The data concerning this issue, however, are complex. Hasher, Stoltzfus, Zacks, and Rypma (1991) and Stoltzfus et al. (1993), using a letter naming task, varied RSIs from 300 ms, 500 ms, and 1,200 ms to 1,700 ms. There was no change in negative priming across these different RSIs (mean effects of 8, 9, 8, and 10 ms, respectively). Similarly, Tipper, Weaver, Cameron, et al. (1991), using a picture naming task, varied RSIs from 1,350 ms and 3,100 ms to 6,600 ms. Stable negative priming occurred at all delays (mean effects of 10, 10, and 22 ms, respectively). According to these data, then, negative priming persists over time, at least through 6 s.

Neill and Westberry (1987), however, using RSIs of 20, 520, 1,020, and 2,020 ms in the context of a continuous series of Stroop items, reported a reliable decline in negative priming over these intervals (mean effects of 18, 26, 11, and —5 ms, respectively). Neill and Valdes (1992) found similar results with a letter-matching task, in which participants were presented with a string of five letters (e.g., *CACDC)* and were required to indicate by a keypress whether the second and fourth letters were the same or different. In their experiment, negative priming declined across RSIs of 500, 1,000, 2,000, 4,000, and 8,000 ms. However, the negative priming effects at the longest RSIs, although reliably smaller than those at the 500-ms RSI, were still significant (Neill & Valdes, 1992, Experiment 1); furthermore, when the 500-ms RSI data were excluded from analyses, the interaction between the negative priming effect and RSI disappeared. Thus, the data from Neill and Valdes suggest that negative priming substantially declines after 500 ms but then remains stable at a lower level for at least 8 s. One potential explanation for the decline in negative priming after 500 ms, coupled with the small but reliable negative priming for up to 8 s, is discussed in the Mechanisms of Negative Priming section.

Neill and Valdes (1992) argued that a basic experimental de-sign variable may be responsible for differences in the patterns of maintenance versus decline in negative priming tasks. They noted that in all experiments in which a decline in negative priming was seen, RSI was varied within participants, whereas in experiments in which negative priming remained stable, RSI was varied between participants. Neill and Valdes attributed this difference, in part, to different processing strategies that participants adopted. The issue of strategies in negative priming are discussed in the later section *Impact of Experimental Context and Strategies.* However, recent evidence suggests that the between- versus within-group design manipulations are not the critical determinant of the persistence versus decline for negative priming (Hasher, Zacks, Stoltzfus, Kane, & Connelly, 1995).

In summary, negative priming effects are minimal immediately after selection, as indexed by tasks that either test immediately on selection or that push participants to speed their responses. Instead, negative priming develops sometime after selection has been accomplished. Furthermore, negative priming does not dissipate immediately after a response to a target but persists during subsequent processing of other items and under some circumstances over considerable amounts of time. Although negative priming does decline after 500 ms in some instances, a significant level of negative priming endures for up to 8 s. If negative priming is produced by inhibition, then these data suggest that inhibition develops some time after selection and that it is sustained for several seconds, even during further processing of new information.

Negative Priming and Distractor Interference

Further evidence that inhibition serves a postselection function comes from comparisons with the attentional index of distractor interference. Under modal circumstances, distractor interference is measured by comparing response times on trials containing both a target and a distractor with response times on trials containing a target alone. Interference thus reflects the extent to which a distractor disrupts the selection of, and response to, a concurrently presented target.

Because negative priming and interference were both initially assumed to index inhibitory distractor processing, one might expect these two measures to covary: High levels of negative priming should be associated with low levels of interference (Beech, Baylis, Smithson, & Claridge, 1989; Houghton & Tip-per, 1994; Tipper, Eissenberg, et al., 1992). It also follows that groups that are more susceptible to interference (e.g., children and patients with schizophrenia) should also demonstrate deficits in negative priming (Beech & Claridge, 1987; Tipper, 1991; Tipper & Baylis, 1987; Tipper, Bourque, Anderson, & Brehaut, 1989).

The evidence regarding the relation between negative priming and interference has been addressed by correlational comparisons as well as by between- and within-group comparisons. The predicted inverse relation has been widely, though not uniformly, reported. One example of the inverse relation between negative priming and interference was reported by Allport, Tipper, and Chmiel (1985). They examined negative priming with picture stimuli under selection conditions in which interference from the distractor was minimal (because the target picture was in a predictable location) versus under conditions in which interference from the distractor was greater (because the target picture was in an unpredictable location). In the easy selection condition, negative priming was significant *(M* = 22 ms), but interference was not *(M* = 5 ms); in the difficult selection condition, negative priming was not reliable *(M* = 14 ms), but interference was *(M* = 27 ms).

A similar pattern has been found in comparisons of groups who suffer more versus less extensively from distractor interference. For example, children show both greater interference and diminished negative priming relative to young adults in a Stroop naming task (Tipper et al., 1989). This pattern has been reported in other tasks for other groups as well, including older adults (McDowd & Oseas-Kreger, 1991) and young adults who score high on a self-report measure of everyday cognitive failure (Tipper & Baylis, 1987; but see Kane, Hasher, Stoltzfus, Zacks, & Connelly, 1994). Finally, significant negative correlations between negative priming and interference have been found within groups (Beech, Baylis, Smithson, et al., 1989, Experiment 1 [*r* = —.35] and Experiment 2 [*r* = —.52]; Kane, Hasher, et al., 1994 *[r* = —.36]; Sullivan & Faust, 1993 *[r* = —.32 I), such that those who show more negative priming tend to show less interference.

However, negative priming and interference do not always vary consistently across tasks, experimental conditions, or between groups. For example, participants identifying letters with vocal responses demonstrate greater interference *(M* = 42 ms) than those making keypress responses *(M* = 33 ms), yet the extent of negative priming across these conditions does not differ *(M* = 10 ms and *M* = 8 ms, respectively; Tipper, Mac-Queen, & Brehaut, 1988). Similarly, when distractor items are black numbers, participants counting red numbers demonstrate reliably more interference *(M*= 24 ms) than those counting red letters *(M* = —2 ms), but the negative priming for these conditions does not differ *(M* = 13 ms for both conditions; Driver & Tipper, 1989).

As well, several studies have failed to find reliable within-group correlations between negative priming and interference (Beech, Baylis, Smithson, et al., 1989, Experiment 3; Beech & Claridge, 1987; Flowers, Heppner, & Muraoka, 1990; Stoltzfus et al., 1993); participants showing more interference do not necessarily show less negative priming. Moreover, between-group comparisons do not always produce the predicted inverse relationship. For example, although negative priming and interference were negatively correlated within groups of younger and older adults in the Kane, Hasher, et al. (1994) study, the two effects did not vary as expected between the two age groups: Older adults, who failed to show any negative priming in a word naming task, did not show greater interference effects than younger adults, who did show negative priming. Failures to obtain an increase in interference effects with other groups showing deficits in negative priming have also been reported, for ex-ample, with schizophrenic patients (Beech, Powell, McWilliam, & Claridge, 1989), schizotypes (Beech, Baylis, Smithson, et al., 1989), older adults (Stoltzfus et al., 1993), and children (Tipper et al., 1989, Experiment 3).

Finally, positive relations between interference and negative priming across tasks have also been reported. E. Neumann (1993), for example, found that a distractor positioned near the target not only was more interfering than a distant distractor but also elicited more negative priming. Similar positive relations between interference and negative priming across tasks or stimuli are found in data from Neill and his colleagues (Neill & Lissner, 1988; Valdes, 1993; Valdes & Neill, 1993).

It should be noted that not all studies have measured interference using the modal test of comparing distractor-present versus distractor-absent trials. Other measures of interference have included comparisons of color naming to Stroop words versus to colored Xs (e.g., Tipper et al., 1989), naming color patches in the presence of color names versus white +s (e.g., Beech & Claridge, 1987), and shape identification in the presence of one versus two distractors (Yee, 1991); and responding in the presence of distractor letters versus numbers (Driver & Tipper, 1989), distractor pictures versus picture fragments (e.g., Tipper, 1991), and large versus small distractors (E. Neumann, 1993). A careful examination of the relation between negative priming and interference in these tasks does not illuminate the source of the discrepancies in the relation between the negative priming effect and interference effects throughout the literature.

A final consideration regarding the relation between negative priming and interference is the argument put forth by Duncan and Humphreys (1992) that one critical determinant of distractor interference in visual search tasks is the featural similarity between targets and distractors. Although findings from visual search studies support this view, the patterns of data out-lined do not readily enable a transposition of this view to these issues. In negative priming tasks, where there is typically just one target and one distractor per stimulus display, there appears to be no obvious or consistent relation between target and distractor similarity and the covariation of interference with negative priming effects. Thus, the stimulus and procedural variables that influence the ease of target selection may not regularly influence negative priming.

Despite the complexity of these correlational data, they permit some basic conclusions regarding the function of inhibition. If inhibition were operating during current selection to produce negative priming, interference should show a systematic inverse relation to negative priming. The lack of a consistent relation between negative priming and interference thus suggests that the mechanism responsible for negative priming may not reliably function during selection.

Summary of the Function of Inhibition

Together, findings from studies examining both the time course of negative priming and the relation between negative priming and interference are consistent with the position that the mechanism responsible for identity negative priming operates after selection (Stoltzfus et al., 1993; Tipper, Weaver, Cameron, et al., 1991): Negative priming is not evident immediately following selection, as would be expected if inhibition were operating during selection; instead, negative priming requires time to develop and persists over time and additional processing. Furthermore, if inhibition were acting to aid selection, and if this inhibition underlies negative priming, then low levels of interference would be consistently associated with high levels of negative priming. However, interference shows no consistent relation with negative priming. Together, this evidence suggests that inhibition does not function to aid current selection but instead operates after selection is complete to deny activation to recently rejected information.

Processing Locus of Negative Priming

If inhibition operates at a peripheral level of the information-processing system, that is, at perceptual or motoric levels, then the negative priming it produces should be either stimulus or response specific. Negative priming should occur only when (a) the current target item is perceptually identical to the previous distractor or (b) the identical type of response is made across trials. Alternatively, inhibition may function at a central level, not tied to a specific stimulus or response but operating more centrally at the level of representations and access to effectors. If the latter is correct, negative priming should occur despite changes in stimulus characteristics from a prime to a test trial and despite changes in response modes across pairs of trials.

The data are quite clear in showing that negative priming occurs despite physical changes in stimulus type from prime to test trials, including changes from uppercase to lowercase letters (Allport et al., 1985; Lowe, 1985), from pictures to words (Driver & Tipper, 1989, Experiment 3; Tipper & Driver, 1988), across sensory modalities (Driver & Baylis, 1993; Greenwald, 1972), and from a word or picture to its semantic associates, as from the distractor *dog* to the target *cat* (Allport et al., 1985; Tipper, 1985; Yee, 1991; but see Fox, in press).

Moreover, negative priming is tied to reusing neither a specific response nor the same response mode across trials: In a letter-matching task in which participants judged whether two target letters were the same or different, negative priming did not vary with response congruity between prime and test trials (Neill, Lissner, & Beck, 1990). Equivalent negative priming is found whether two consecutive responses are conceptually and motorically identical (e.g., same—same) or different (e.g., same—different). Additionally, participants responding to target letters either vocally, with a keypress, or by alternating between vocal and keypress responses between pairs of trials, all showed equivalent negative priming (Tipper et al., 1988). The fact that negative priming occurs despite changes in either the perceptual characteristics of stimuli or the specific response and response mode suggests that if inhibition underlies negative priming, it operates at a central level rather than at a specific perceptual, featural, or response level.[3]

One limitation of the conclusion that inhibition operates at a central, abstract level, however, is that almost all studies exploring the locus of inhibition use naming tasks in which the identity of the stimuli is central for response. The level at which inhibition operates may be influenced by task demands (Neill, Valdes, & Terry, 1995), and thus the finding that inhibition operates at a categorical level may be driven by the semantic nature of naming tasks. The few studies that have investigated the locus of inhibition using nonsemantic, perceptual matching tasks (e.g., Neill, 1991; Yee, 1991) have produced equivocal results regarding the level at which inhibition operates. A richer literature is needed in which the locus of inhibition is explored using a variety of different response tasks.

Thus, in tasks requiring stimulus identification, inhibition operates at an abstract level rather than a perceptual level or a response level, occurring across semantic associates and different response modes.

Individual Differences in Negative Priming

The data reviewed thus far suggest that inhibition functions at an abstract level to prevent already selected-against information from intruding into current processing. Similar assumptions about the function of inhibitory mechanisms have been posited by researchers of special populations, who have argued that weakened inhibitory mechanisms are at least partially responsible for impairments in cognitive functioning demonstrated by such groups as older adults (e.g., Dempster, 1992; Hasher & Zacks, 1988; Zacks & Hasher, 1994) and patients with schizophrenia (e.g., Frith, 1979; Gray, Feldon, Rawlins, Hemsley, & Smith, 1991). Investigators have used the negative priming task to measure attentional processing in these populations in an effort to link inhibitory deficits in the negative priming task with more global behavioral consequences (e.g., distractibility and reduced ability to form a coherent representation of discourse). The results generally confirm initial pre-dictions: Decrements in negative priming have been reported for population groups such as children (Tipper et al., 1989), older adults (e.g., Hasher et al., 1991; McDowd & Oseas-Kreger, 1991), and patients with schizophrenia (e.g., Beech, Powell, et al., 1989). However, there are systematic exceptions to these group deficits in negative priming. A careful analysis of these instances leads to the proposal that two independent inhibitory systems may produce negative priming: one system operating on the identity of distractors, the other on the location of distractors. There is clear evidence from older adults that one system may continue to operate efficiently, whereas the other one becomes inefficient. We now consider these findings.

Developmental Patterns

Within the developmental literature, the major assumption has been that negative priming and interference are both related to inhibitory processing. Researchers have attempted to assess developmental changes in inhibitory processing by exploring negative priming in children and older adults, who have been shown elsewhere to demonstrate enhanced susceptibility to distraction. Children, for example, suffer greater distraction effects than young adults across a variety of tasks (for reviews, see Bjorklund & Harnishfeger, 1990; Davies, Jones, & Taylor, 1984; Lane & Pearson, 1982). Indeed, as early as 1973, Doyle hypothesized that young children's vulnerability to interference from distraction resulted from an inability to inhibit intrusions from unattended information sources. Young children also show weakened negative priming effects, as demonstrated by Tipper et al. (1989) using both a Stroop color naming task and a picture identification task. These data suggest that the development of attentional inhibitory mechanisms may not be complete by early childhood.

By early adolescence, however, at least some selection mechanisms seem to be operating efficiently: Although adolescents suffer greater interference from distracting information than young adults in a letter naming task, they do demonstrate negative priming effects that are equivalent to, or even greater than, those seen for young adults (Hasher, Quig, Stoltzfus, & Goldstein, 1995).

According to one cross-sectional study (Oseas-Kseger & McDowd, 1992), inhibitory attentional processes (as measured by negative priming) remain stable across early adulthood, be-ginning to decline around age 40. Although the research on se-lection mechanisms with middle-aged individuals is sparse, extensive research with older adults (ages 60 to 80 years) is consistent with the claim that attentional processing is disrupted late in life (e.g., Hasher & Zacks, 1988; Madden, 1990). The performance of older adults is differentially impaired by the presence of distracting items across a variety of attentional tasks, including Stroop (e.g., Cohn, Dustman, & Bradford, 1984; Comalli, Wapner, & Werner, 1962) and visual search tasks in which the location of the target is unpredictable (e.g., Fisk & Rogers, 1991; Madden, 1983; Plude & Hoyer, 1985). Older adults may also have difficulty habituating to irrelevant auditory stimuli (McDowd, Oseas-Kreger, & Filion, 1994).

In their discussion of age-related deficits in cognitive performance, Hasher and Zacks (1988) argued that the efficiency of the inhibitory processes that control access to working memory decreases with age. As a consequence, older adults may allow more marginally relevant and irrelevant information into working memory. Furthermore, once this irrelevant information enters working memory, inefficient inhibitory mechanisms fail to dampen its activation, leading to its sustained presence. Should goals shift while information is in working memory, inefficient inhibition will also fail to dampen activation to the no longer relevant ideas. This view predicts a range of phenomena in aging, from heightened susceptibility to sources of proactive forgetting (e.g., Gerard, Zacks, Hasher, & Radvansky, 1991; Winocur & Moscovitch, 1983) to patterns of difficulties in discourse comprehension (e.g., Hamm & Hasher, 1992; Hasher & Zacks, 1988; Stoltzfus & Hasher, 1995; Stoltzfus, Hasher, & Zacks, in press).

Researchers have recently used the negative priming paradigm to investigate inhibitory functioning in older adults. If inhibitory mechanisms weaken with age, and if these mechanisms underlie negative priming, then older adults should demonstrate reductions in negative priming. Results across a variety of experiments have supported this hypothesis. For example, in a letter naming task, younger adults showed negative priming, whereas older adults did not (Hasher et al., 1991). Other re-searchers have also reported diminished negative priming in older adults with a variety of stimuli, including spatially separated letters (Stoltzfus et al., 1993), superimposed letters (McDowd & Oseas-Kreger, 1991), pictures (Tipper, 1991), and words (Kane, Hasher, et al., 1994). The reduction in negative priming for older adults, then, appears to be a general phenomenon and is not tied to specific stimulus types (but see later discussion of Sullivan & Faust, 1993).

The failure to find negative priming with older adults cannot be accounted for by the suggestion that inhibitory processes follow a different time course for younger and older adults. Older adults do not show negative priming effects at short RSIs (300 and 500 ms), as might be expected if inhibition were quick to build up and difficult to sustain. Nor do they show negative priming at long RSIs (1,200 and 1,700 ms; Hasher et al., 1991; Stoltzfus et al., 1993), as might be expected if inhibition takes longer to build because older adults are generally slower than younger adults (Salthouse, 1985). Older adults do not show negative priming effects for exposure durations from 300 to 500 ms, with longer durations presumably enabling more complete processing of distractors (Kane, Hasher, et al., 1994). Thus, stimulus timing variables are not responsible for the lack of negative priming generally seen in older adults. Instead, the evidence suggests a genuine deficiency in inhibition associated with aging (but see *Group Differences in Location-Based Tasks* for an exception).

Schizophrenic Patients

Recent models of schizophrenia suggest that some of the behavioral symptoms of this disorder may result from weakened inhibitory filtering systems. Frith (1979), for example, postulated that the three positive symptoms of schizophrenia—hallucinations, delusions, and thought disorder—can be attributed to an inability to filter irrelevant information from consciousness and a subsequent hyperawareness of multiple interpretations of events (see also Gray et al., 1991). Although conclusions about this group should be drawn tentatively because of its tremendous heterogeneity (Carson & Sanislow, 1992), such hypothetical deficits in attentional filtering by schizophrenic patients have been supported by numerous empirical investigations. For example, patients with schizophrenia have difficulty ignoring distractors in sorting and categorization tasks (e.g., Chapman, 1958; Weinberger, 1986), in dichotic listening tasks (e.g., Spring, Lemon, Weinstein, & Haskell, 1989), in vigilance tasks (e.g., Lenzenweger, Cornblatt, & Putnick, 1991), and in location cuing tasks (Posner, Early, Reiman, Pardo, & Dhawan, 1988). If the same inhibitory mechanisms that are deficient in schizophrenic patients also operate in negative priming, then schizophrenic patients should fail to demonstrate the effect.

As predicted, schizophrenic patients do not show negative priming (Beech, Powell, et al., 1989; Laplante, Everett, & Thomas, 1992), nor do "control" participants who score high on schizotypy scales, such as the Personality scale of the Eysenck Personality Questionnaire (Eysenck & Eysenck, 1975; see Bullen & Hemsley, 1984) and the Schizotypal personality scale (STA) of the Psychotic Traits Questionnaire (Claridge & Broks, 1984; see Beech & Claridge, 1987; Beech, Baylis, Smith-son, et al., 1989, for brief exposure condition only). In addition, chlorpromazine, an antipsychotic drug, has been found to in-crease negative priming in normal participants (Beech, Powell, McWilliam, & Claridge, 1990). Although thus far there is no direct evidence, this suggests that the use of chlorpromazine with schizophrenic patients not only alleviates psychotic symptoms but also may restore their ability to inhibit. Together, these data support the suggestion that the inhibitory mechanism underlying negative priming is implicated in schizophrenic patients' behavioral symptoms, and furthermore that deficits in inhibitory processing may have important implications for broader cognitive functioning.

Group Differences in Location-Based Tasks

The group difference studies discussed thus far have explored negative priming using identity-based tasks, that is, tasks in which participants select an object on the basis of some physical attribute, like color or font, and respond to the object's identity (refer to Figure 1). An alternative type of selection task is a location-based task, in which participants again select on the basis of a physical attribute but now respond to the object's location. For example, participants might see a visual display consisting of four distinct locations, one of which contains a target item (e.g., a bold letter) and one of which contains a distractor item (e.g., a normal letter). The participants' task is to select the target item and respond to its location, either with a corresponding keypress or a vocal response.

Negative priming is measured on those trials in which the test target appears in the location that was previously occupied by the prime distractor. This condition is compared with a control condition in which none of the items across prime—test pairs appear in the same locations (see Figure 2). Any response impairment for the negative priming condition is thought to reflect that the location of distracting information is suppressed, and as a result, the response to any new information that appears in that suppressed location is impeded.

In many ways, the patterns of data for identity inhibition and location inhibition are very similar; however, critical findings regarding group differences on the two types of negative priming tasks distinguish location inhibition from identity inhibition. We first review the similarities between location and identity negative priming and then detail the group difference data that suggest that location negative priming may derive from an entirely separate inhibitory neurobiological system.

Data from both the time course of location negative priming and its relation with interference suggest that the function of location inhibition may be similar to that of identity inhibition. With respect to the time course of location negative priming, some evidence indicates that it remains stable across both intervening events (provided those events are not surprising) and RSIs of over 6 s (Tipper, Weaver, Cameron, et al., 1991); other evidence, however, suggests that it decays significantly across RSIs from 500 ms *(M* = 32 ms) to 4,000 ms *(M* = 17 ms; Neill, Valdes, Terry, & Gorfein, 1992). Despite this gradual decay, significant location negative priming occurs at 4,000 ms. Thus, as inferred with identity inhibition, location inhibition seems to persist for several seconds after selection, suggesting that one purpose of location inhibition may be to facilitate further target processing by preventing attention from returning to selected-against locations.

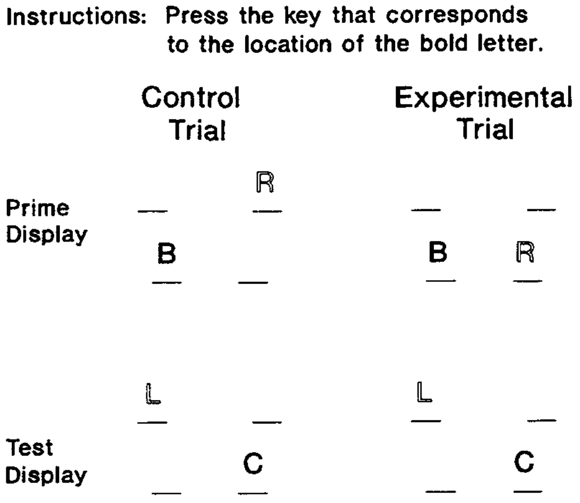

Figure 2. Example trial for location negative priming task. Note that in the experimental trial, the target letter on the test display appears in the same location that was occupied by the distractor on the prime display.

Data regarding the relation between location negative priming and interference also mirror findings for identity negative priming: Across studies, there is no consistent relation. Although a few studies indicate a positive relation between location negative priming and interference, such that conditions that result in greater interference also produce greater negative priming (Tipper, Lortie, & Baylis, 1992, Experiment 5; Valdes, 1993), several other investigations failed to find any systematic relation between location negative priming and interference (e.g., Connelly & Hasher, 1993; Tipper, Weaver, Cameron, et al., 1991, Experiments 3 and 5; Tipper, Weaver, Kirkpatrick, & Lewis, 1991). If location inhibition produces negative priming during current selection by dampening areas containing distraction, negative priming should show an inverse relation to interference, with high levels of negative priming being associated with low levels of interference. Thus, as with identity negative priming, the lack of a consistent relation between location negative priming and interference suggests that location inhibition does not function primarily as an aid to current selection.

Finally, location negative priming, like identity negative priming, occurs at an abstract, categorical level rather than a peripheral level, at least with respect to output: Location negative priming occurs for both keypress responses (Connelly & Hasher, 1993; Tipper, Brehaut, & Driver, 1990; Tipper, Eissenberg, et al., 1992; Tipper, Weaver, Cameron, et al., 1991; Tipper, Weaver, Kirkpatrick, et al., 1991) and vocal responses (Connelly & Hasher, 1993; but see Tipper, Weaver, Kirkpatrick, et al., 1991) and when participants must switch between key-press and vocal responses between prime and test trials (Tipper, Weaver, Kirkpatrick, et al., 1991). As well, location negative priming seems to occur independent of task demands: Participants naming colored letters that appear in one of four locations show reliable location negative priming, even when spatial location is not a salient part of selection or response (Connelly & Hasher, 1993). Thus, if location inhibition is responsible for location negative priming, then it appears to be a fundamental aspect of information processing.

Findings regarding the time course of location negative priming, its relation to interference, and the level at which it operates are all similar to those with identity-based tasks. One set of findings, however, clearly distinguishes location negative priming from identity negative priming: Despite children and older adults' failure to show negative priming in identity-based tasks (Hasher et al., 1991; Kane, Hasher, et al., 1994; McDowd & Oseas-Kreger, 1991; Stoltzfus et al., 1993; Tipper, 1991; Tipper et al., 1989), both of these groups demonstrate significant negative priming in location-based tasks (Connelly & Hasher, 1993; Tipper & McLaren, 1990).

Tipper and McLaren (1990) found, for example, that first graders and sixth graders showed significant negative priming for location, with an effect size equivalent to that demonstrated by young adults. Similarly, Connelly and Hasher (1993) demonstrated significant negative priming for older adults across three experiments using location-based tasks. In all cases but one, the negative priming for older adults was equivalent to that shown by young adults. The one exception occurred in Experiment 3, where negative priming for location, identity, and the combination of the two were all measured in the same task. Here, young adults demonstrated negative priming for both the identity and the location of stimuli and an additive effect when the two were combined (i.e., when the test target was both identical to, and appeared in the same location as, the prime distractor). Older adults, however, showed negative priming only for stimulus location, not for stimulus identity, and the effect of combining the two was equivalent to the effect of negative priming for location alone. This final experiment provides a straightforward, within-subjects demonstration that older adults show an impairment in negative priming for the identity of distractors but preserved negative priming for their location.

Whereas the inhibition of identity information appears to operate at a relatively late stage of stimulus processing, the same may not be true for location inhibition. For both younger and older adults, distractor locations are inhibited in localization tasks and in identity tasks (where location is not integral to selection or response; Connelly & Hasher, 1993, Experiment 3). For neither age group, however, is identity information inhibited in location tasks (where identity information is irrelevant to task demands; Connelly, Hasher, & Kimble, 1992). These findings suggest that these inhibitory mechanisms may function at different stages of the selection sequence, with location information being inhibited at a relatively early processing stage and identity information being inhibited at a relatively late stage.

The differential patterns of age-related deficit and sparing of identity versus location negative priming may also indicate that separate neural pathways underlie the processing of identity and location information, and thus that two separate inhibitory systems may exist (Connelly & Hasher, 1993; for alternative interpretations of these data, see Fox, in press; Park & Kanwisher, 1994; Tipper, Weaver, & Milliken, 1994). There is some neurophysiological support for this notion (Ungerleider & Mishkin, 1982), in that at least two distinct pathways carry visual information from receptors through the cortex: a more ventral, occipitotemporal pathway specialized for carrying information about identity (Miller, Li, & Desimone, 1991) and a more dorsal, occipitoparietal pathway specialized for processing spatial information (Desimone, Albright, Gross, & Bruce, 1984). By this view, then, inhibitory processing in the ventral pathway may deteriorate with age, whereas inhibitory processing along the dorsal pathway may be spared.

Research in visual selective attention further suggests that age differences in visual search tasks are attenuated when the locations of targets and distractors are predictable as compared with when they are not (Madden, 1983; Plude & Hoyer, 1985). As well, the disruptive impact of distracting information on reading for older adults is greatly reduced if that distracting material appears in a predictable location compared with an unpredictable location (Carlson, Hasher, Connelly, & Zacks, in press; Connelly, Hasher, & Zacks, 1991).

Together, these data suggest the importance of the location system in preserved intellectual functioning, particularly in the face of a declining ability to inhibit identities. Behavioral evidence is thus consistent with the proposal that spatial processing is preserved with age, suggesting that location processing systems enjoy a relatively privileged developmental prominence.

By extension, an interesting question becomes whether schizophrenic patients are able to inhibit location information. Given their extreme cognitive limitations relative to normal older adults, one might predict that they cannot (see also Posner et al., 1988); furthermore, one might speculate that what qualitatively sets schizophrenic patients apart from other patient groups is their inability to effectively inhibit on the basis of location information and that this specific deficit, which other-wise spares young children and older adults from processing irrelevant perceptual and cognitive information, might be a major contributor to the extent of their cognitive impairments.

Summary

Several populations, such as older adults, young children, and schizophrenic patients, demonstrate deficits in negative priming for the identity of an item, suggesting that they suffer from diminished inhibitory processing. Results from location-based tasks, however, indicate that some inhibitory processing may be fully functional for children and older adults, consistent with the view that spatial information may be processed separately from identity and that the inhibitory mechanisms in the spatial system are preserved throughout the life course. By contrast, inhibitory mechanisms in the identity system are not privileged.

Impact of Experimental Context and Strategies

An examination of the impact of experimentwide context and of strategies on negative priming is of central importance to an understanding of the nature of inhibition. For example, any changes in negative priming that occur with manipulations of experimental context (e.g., the proportion of different trial types in a series) may indicate that inhibition is a flexible, adaptive mechanism that is susceptible to shifts in strategies.

Preliminary evidence that negative priming is affected by experimental context comes from experiments demonstrating a reversal of the negative priming effect when selection is not required on test trials, that is, when the test trial target appears without a distractor (Lowe, 1979). In one experiment, for ex-ample, Stroop color word stimuli were used on prime trials, with color patches rather than Stroop color words on test trials (Experiment 3). Because color patches contain no distracting word to conflict with the color naming, no selection was involved in responding on test trials. For negative priming trials, the test color patch matched the distractor word of the preceding Stroop stimulus. When all test items in the list were nonconflict stimuli (i.e., color patches), the negative priming effect was either completely eliminated or even reversed; that is, participants were *faster* in responding when the prime distractor word predicted the test color patch.

The facilitation found in the negative priming trials with non-conflict stimuli suggests that negative priming effects are not an entirely automatic consequence of selecting a target in the presence of a distractor on a prime trial. That is, as measured by negative priming, inhibition is not an essential part of selection. Furthermore, negative priming appears to be susceptible to alterations in participants' expectations and strategies. Indeed, Lowe (1979) proposed that negative priming is *only* found when participants expect processing difficulties on test trials, as would occur when they expect to make a selection in responding to the target. Results from another experiment by Lowe (1979, Experiment 4), in which combinations of Stroop color words, random colored letters, and color patches were used as test items across different groups, confirmed his prediction: Negative priming effects maintained for all conflict stimuli (i.e., all Stroop color words, regardless of what stimuli they were interspersed with) and for colored letters intermingled with Stroop stimuli. Facilitation effects were observed, however, for all non-conflict stimuli (i.e., color patches) and for colored letters interspersed with nonconflict stimuli. Thus, colored letters were associated with both slowing and speeding effects, depending on the experimentwide context in which they occurred.

To account for these findings, Tipper and Cranston (1985) further elaborated on the effects of context on inhibition. Specifically, Tipper and Cranston proposed that the presentation of stimuli results in the activation of their internal memory representations. The representations of stimuli that are selected for action are then translated into responses, whereas the representations of stimuli selected against are blocked from all overt response mechanisms (see also Navon, 1989a, 1989b). Thus, ex-citatory and inhibitory processes operate independently, with the result that distracting items have activated representations but inhibited outputs to response; this output inhibition should then result in a delay in response to that item if it subsequently appears as a target.

One critical feature of this inhibition model is that the inhibition associated with response output is quite labile, for it can be influenced by processing demands and participants' strategies. When participants expect the processing of the test display to be difficult (e.g., that it will require selection), participants maintain a "selection state" during which inhibition persists (Tipper & Cranston, 1985). Participants' expectancies are determined both by the proportion of trials that require selection and by the type of stimuli used on nonconflict trials. When a large proportion of trials involve selection or when nonconflict stimuli closely resemble conflict stimuli, expectations of processing difficulty remain high, and negative priming is seen. This occurs because participants have blocked the representations of selected-against stimuli from response output. However, when participants do not expect processing difficulty on the test, either because all test items are nonconflict stimuli (i.e., only targets) or because some test items clearly do not require selection (e.g., color patches), they do not maintain this selection state. As a result, inhibition of the response output for previously distracting items quickly dissipates, although the activation associated with their internal representations remains.

Thus, if a previously distracting stimulus becomes a target on a nonconflict test trial, response to it is facilitated. This inhibition model (Tipper & Cranston, 1985) can ac-count both for the fact that negative priming is found whenever processing difficulties are expected on test trials and also for the fact that these effects are reversed for conditions in which selection is clearly not required on test trials (Lowe, 1979). For example, Tipper and Cranston (1985) and Allport et al. (1985) found negative priming when test trials involved selection of a target from among distractors but found facilitory effects when tests consisted of a solitary target letter (as did Lowe for color patches). Additionally, Neill and Westberry (1987), using a Stroop task, demonstrated negative priming for all stimuli when conflict stimuli (Stroop color words) were paired with nonconflict stimuli (colored Os) on test trials and the experimentwide ratio of conflict stimuli to nonconflict stimuli was 3:1. These findings support the view that negative priming is found when participants expect to make a selection on the test trial, even if on any given trial no selection is required. To our knowledge, there are only two experiments in which negative priming is found in the complete absence of conflict stimuli on the test trial (Hoffman & MacMillan, 1985; Yee, 1991). Both of these experiments used lexical decision tasks, as discussed in the section *Contexts That Induce Episodic Retrieval,* which may allow for processes other than inhibition to produce negative priming.

In summary, data from studies using nonconflict stimuli generally indicate that negative priming occurs whenever the majority of test trials require selection; facilitation occurs when test trials are clearly or predictably nonconflict (for similar conclusions, see Fox, in press). If inhibition is indeed responsible for negative priming, then this pattern of data suggests that inhibition is a flexible mechanism, affected by experimental context and susceptible to participants' strategies.

Further evidence that strategies, context, or both affect negative priming comes from explorations of reports of awareness of the presence of negative priming trials. Findings from Hasher et al. (1991) and Stoltzfus et al. (1993) indicate that participants who are aware of the negative priming manipulation are sometimes able to use this information to predict test targets. As a result, these participants show a small facilitation rather than an impediment when responding in the negative priming condition. However, awareness of the presence of negative priming trials influences performance only under circumstances in which the knowledge is usable. For example, in the blocked trials procedure used by Hasher et al. and Stoltzfus et al., facilitory effects of awareness were seen only for longer RSIs. As well, when negative priming trials comprise a relatively small pro-portion of the entire experiment and are randomly interspersed with control trials, awareness does not benefit performance (Neill & Valdes, 1992, Experiment 3).

In summary, context variables clearly influence the negative priming effect: Negative priming can be reduced or even re-versed when participants do not need to select on test trials or when they become aware of experimental conditions and have the opportunity to use that knowledge. The best explanation for these data is the inhibition model (Tipper & Cranston, 1985), which suggests that changes in selection requirements, awareness, types of trials across an experiment, and instructions for responding might all induce participants to abandon "selection states" when responding, resulting in a rapid dissipation of inhibition and consequently a reduction or reversal of negative priming.

Summary of the Literature Review

We now summarize the major empirical findings regarding negative priming and use them to delineate the nature of the inhibitory process invoked in selective attention. First, studies investigating the time course of negative priming suggest that inhibition does not operate immediately and that it may persist for some time, even during processing of subsequent items. Second, experiments exploring the relation between negative priming and interference fail to demonstrate a consistent relation between these measures, suggesting (a) that they are at least partially independent and (b) that inhibition does not influence interference, or at least does so in ways that have yet to be discerned. Together, these data depict an inhibitory mechanism that functions not as an aid to current selection but as a means of preventing recently ignored information from regaining response access, thus facilitating coherent on-line processing (Tipper, Weaver, Cameron, et al., 1991; Stoltzfus et al., 1993).

Third, experiments manipulating stimulus type and response mode indicate that identity inhibition, at least, is not confined to the level of perceptual features or to the level of peripheral response; rather, inhibition may function at a more central level, blocking semantic representations of distracting stimuli from response. Fourth, studies exploring group differences in negative priming demonstrate that certain populations—including children, older adults, and schizophrenic patients—fail to show negative priming, at least for stimulus identity. Such findings suggest that these populations may suffer from deficient inhibitory functioning for identity information. Additionally, several studies show preserved location negative priming for children and older adults, suggesting the existence of two separate inhibitory systems: one for stimulus identity and the other for spatial location.

Finally, inhibition appears to be an adaptive, flexible mechanism; inhibitory effects can be eliminated or even reversed with changes in participants' strategies and in experimental context (e.g., Hasher et al., 1991; Lowe, 1979).

Mechanisms of Negative Priming

Although the preceding review suggests strong support for the inhibition view (Tipper & Cranston, 1985), this view cannot, as we show later, account for all the negative priming data. To make this shortcoming clear, we briefly review the assumptions of the inhibition model and then discuss recent data that are difficult for it to accommodate. These new data suggest that in some experimental contexts, negative priming may have at least two sources: one inhibitory and one memorial. In presenting this explanation, we delineate the specific circumstances under which each of these mechanisms can be expected to operate.

Inhibition View

The inhibition model (Tipper & Cranston, 1985) posits that, if detected, a familiar distractor stimulus activates its internal memory representations. An inhibitory mechanism then functions to decouple the activated representations of distractors from response output. This inhibition is manifest in the delayed response to a distractor item that subsequently becomes relevant (Dalrymple-Alford & Budayr, 1966; Neill, 1977; Tipper, 1985; Tipper & Cranston, 1985). Inhibition thus operates in a *forward* direction: Inhibition of the response to a distracting item on a prime trial impedes responding to that item on the following test trial. The findings reviewed above suggest that for young adults, inhibition is relatively flexible, can operate at a categorical level, and can persist over time and processing of other items.

One significant challenge to the inhibitory explanation of negative priming comes from the work of Neill and Valdes (1992) and Neill et al. (1992), who found a pattern of negative priming that led them to postulate an alternative explanation for the effect. In particular, across several experiments they found a reliable decrement in negative priming as the delay between prime and test trials increased, but only when the length of this delay was manipulated within subjects. If inhibition operates to facilitate future processing, as Tipper, Weaver, Cameron, et al. (1991) and Stoltzfus et al. (1993) have argued, it should do so without regard to the predictability of the intervals between trials. To account for these data, Neill and Valdes and Neill et al. (1992) proposed an alternative explanation for negative priming, described as an episodic retrieval view.

Episodic Retrieval Theory

The episodic retrieval explanation of negative priming, which is based on Logan's (1988) theory of automatization, proposes that the presentation of a stimulus *automatically* evokes the retrieval of the most recent episode involving that stimulus. The retrieved episode contains information (or tags) about the stimulus and its attributes, including the response (or nonresponse) that was made to it. For example, presentation of the letter *B* as a target causes retrieval of the most recent episode containing *B.* If *B* served as a distractor on the previous trial, an *ignore-it* tag is automatically retrieved. Once retrieved, this ignore-it tag necessarily conflicts with the current response requirement (i.e., *name it)* and as a result delays response until the ambiguity between the two tags is resolved. Accordingly, it is the delay caused by response competition that is manifested as negative priming.[4]

In contrast to inhibition, then, which acts in a forward manner to block a *prime* distractor from future response output, episodic retrieval operates in a *backward* direction: Presentation of an item on the *test* trial induces retrieval of a prior episode containing that item, and this retrieved episode bears response information that conflicts with the current goals, causing negative priming. Thus, in an inhibitory view, the presentation of an item as a distractor results in the inhibition of that item, regardless of whether that item subsequently appears as a target, as long as the participant expects to select in the face of distraction. In an episodic retrieval account, by contrast, presentation of an item as a distractor has *no* consequence unless that item reappears on the subsequent trial, at which point its representation as a distractor may be retrieved. If retrieval is successful, the earlier response tag is compared with the current response requirement.

A key assumption in the episodic retrieval theory (Neill & Valdes, 1992; Neill et al., 1992) is that previous episodes are successfully retrieved with varying probabilities. Thus, response code competition is not constant. According to Neill et al. (1992), one variable that determines the probability of retrieving a given antecedent trial is the degree to which that trial is temporally discriminable from previous trials. When the interval (e.g., RSI) between trials is constant *within* a testing session, all trials are equally discriminable from each other, regardless of the particular RSI that is used (see Baddeley, 1976). Thus, in a between-subjects manipulation of RSI, negative priming should be constant across all RSIs, as has been found by Tipper, Weaver, Cameron, et al. (1991) and Stoltzfus et al. (1993). When RSIs vary within a testing session, however, some trials become more temporally discriminable than others: In particular, a short interval between the previous prime trial (Trial *n — 1)* and the current test trial (Trial *n)* makes the prime trial relatively more retrievable than prime trials followed by a long interval. Trials that are more easily retrieved cause greater response competition and greater negative priming than those less easily retrieved. The net effect, according to the episodic retrieval view, is a reduction in negative priming over long RSIs in a within-subjects design.

The episodic retrieval view appears to provide a compelling account of differences in the decline of negative priming in within-subjects as opposed to between-subjects manipulations of RSI. However, there are data that fail to show the expected decline of negative priming in a within-subjects design (Hasher, Quig, et al., 1995). Moreover, episodic retrieval also fails to ex-plain several other findings in the negative priming literature, including portions of the time course data, results from solitary-test experiments, and finally data regarding the relation between negative priming and other stimulus-processing indexes. Each of these problems is discussed in turn.

According to an episodic retrieval model, as RSIs are lengthened in a within-subjects paradigm, temporal discriminability should gradually decrease, and thus negative priming should show a continuous decline over increasing RSIs. It does not: Negative priming is significantly reduced (if it is reduced at all; see Stoltzfus et al., 1993; Tipper, Weaver, Cameron, et al., 1991) only after the shortest RSI (typically 500 ms), but it remains relatively stable from 1,000 to 8,000 ms (Neill & Valdes, 1992).

Furthermore, according to the episodic retrieval theory, decrements in negative priming should occur when items intervene between prime and test trials: The intrusion of an intervening item should decrease the probability of retrieving the critical prime, both by increasing the delay between the prime and test trials (thereby reducing discriminability) and also by causing interference from the intervening event during retrieval of the prime. Moreover, the decrement in negative priming should be especially profound when the intervening item is highly similar to the prime because highly similar items are generally more interfering and hence should disrupt prime retrieval to a greater extent. However, negative priming has been found to persist across intervening trials, even when those trials are very similar to the prime and test trials (e.g., Tipper, Weaver, Cameron, et al., 1991). Thus, although the episodic retrieval view may ex-plain some of the data regarding RSI effects, it is insufficient as a comprehensive account of the current data on the time course of negative priming.

As well, the episodic retrieval view cannot provide a satisfactory explanation for the diminution or reversal of negative priming when test trials do not involve selection (e.g., Lowe, 1979; see *Impact of Experimental Context and Strategies).* If, as Neill and Valdes (1992) and Neill et al. (1992) proposed, episodic retrieval is *automatic,* then it should not be affected by selection demands on the test trial: Negative priming should occur for all trials in which the test target matches the previous distractor, regardless of whether those trials are conflict or non-conflict trials. For the episodic retrieval theory to account for the fact that facilitation, rather than negative priming, occurs for nonconflict test trials, one of two possible scenarios must hold: Either (a) response tags are not linked with the nonconflict stimuli shown on the test trial, and thus provide no confusion when prior response tags are retrieved; or (b) nonconflict trials reduce the probability of retrieving prior episodes, hence reducing the opportunity for competition between tags. Neither of these possibilities, however, seems plausible. In all of the experiments manipulating test selection requirements, the tasks include the need for participants to respond to the nonconflict stimuli, and thus one would assume that response tags are linked to them. Furthermore, there is currently no theoretical basis for the notion that conflict, but not nonconflict, stimuli evoke the retrieval of prior episodes.

Also problematic for the episodic retrieval view are studies that include a target-to-distractor condition, in which the target item on the prime trial becomes the distractor item on the test trial. According to the episodic retrieval view, presentation of the distractor item on the test trial should evoke the retrieval of its most recent presentation, that is, the prime trial on which it had just been a target. The current response requirement for that item (i.e., *ignore)* should then conflict with the previous response requirement (i.e., *respond),* and the time needed to resolve this conflict should result in delayed responding on the test trial, independent of the response codes for the target on the test trial. Thus, the episodic retrieval theory predicts that participants should be impeded in making a response in the target-to-distractor condition. However, participants typically show facilitation in this condition (Effier, 1977a; Hinton, 1976; Kane, Hasher, et al., 1994; Neill, 1978).

Clearly, the episodic retrieval view is inadequate as a comprehensive explanation of negative priming. It does not appear that participants automatically retrieve prior episodes when presented with a stimulus. This is not to claim, however, that participants never engage in episodic retrieval, or that episodic retrieval never underlies negative priming. On the contrary, we propose that certain experimental conditions, contexts, or both induce or encourage participants to use episodic retrieval and that in these situations negative priming largely reflects the operation of code conflict induced by successful retrieval of prior episodes. In the following section, we explain how and why episodic retrieval might be elicited by particular experimental manipulations and present recent data from our laboratory that support the notion that episodic retrieval sometimes produces negative priming.

Limits on Episodic Retrieval

One experimental manipulation designed to elicit episodic retrieval follows from a series of positive priming (Neely, 1977) experiments by Whittlesea and Jacoby (1990). In a typical positive priming study, a participant is first presented with a prime word (e.g., *doctor)* and then a target word (e.g., *nurse)* and must respond to the target, for example, by naming it. Participants are faster when target words are related to primes, the product of spreading activation from the prime to the target (see McNamara, 1994) as well as of strategic processes (Neely, 1991). The extent of facilitation is greater if the target is perceptually degraded, which increases the difficulty of identifying it (Neely, 1991; Stanovich & West, 1979). The enhanced priming found under conditions of visual degradation has been posited to result from an episodic retrieval of the prime and the unitization of this prime with the target (Whittlesea & Jacoby, 1990); that is, under degraded conditions participants are thought to retrieve the prime information to aid in target identification. Several experiments reported by Whittlesea and Jacoby support the suggestion that participants retrieve antecedent primes when identifying degraded targets.

By this account, one critical determinant of whether a prime is retrieved in the identification of a target is the quality of perceptual information that is available about the target. Similar parameters would be expected to occur in the negative priming paradigm: When participants are forced to respond to test items on the basis of limited or degraded information, they may retrieve information from the prime trial. If the retrieved memory carries with it information that conflicts with information needed to respond to the test, response time is slowed. Negative priming may thus be expected to reflect episodic retrieval when test stimuli are degraded in some way. Finally, and in parallel with effects seen in the positive priming paradigm, negative priming effects will be larger when participants use episodic retrieval than when they do not. However, participants do not need to use retrieval when the stimulus display can be easily perceived. Under these conditions, negative priming should reflect only inhibitory processes.

The predictions regarding performance under diminished perceptual conditions were tested in a series of experiments by Kane, May, Hasher, Rahhal, and Stoltzfus (1995). In their first experiment, Kane, May, et al. used a within-subjects design to manipulate the amount of information available about *test* targets by varying their visual quality. To do this, all the prime trials and half of the test trials contained normal, visually intact words, whereas the remaining test trials contained either a de-graded target or a degraded distractor (the stimuli were overlaid with visual noise). The results of this study confirmed the initial predictions: When test targets were visually degraded, negative priming effects *(M* = 22 ms) were three times the size of those found for normal, nondegraded stimuli (M = 7 ms). These data are consistent with the prediction that the presence of degraded test targets induces episodic retrieval, which in turn results in enhanced negative priming. Also consistent with the hypothesis that two different processes underlie the negative priming effects for nondegraded and degraded conditions was the findings that negative priming effects in the two conditions were *not* correlated. If the same mechanism were responsible for the negative priming effects in both the degraded and the nondegraded conditions, the two effects should be *positively* correlated.

Further support for the view that negative priming reflects inhibitory processing under normal viewing circumstances, but episodic retrieval under degraded conditions, comes from the data of older adults tested in the study by Kane et al. (1995). Older adults failed to show negative priming for normal, undistorted stimuli *(M* = —1 ms), thus replicating previous findings of diminished negative priming for older adults (e.g., Hasher et al., 1991; McDowd & Oseas-Kreger, 1991; Tipper, 1991). However, when test targets were degraded, older adults demonstrated *significant* negative priming *(M* = 28 ms) that was not different from the amount found for younger adults under the same circumstances. As with younger adults, the extent of negative priming in the degraded condition was not correlated with that in the nondegraded condition for older adults. Given (a) that the stimulus degradation occurred on *test* trials, (b) that the lack of a positive correlation for negative priming on de-graded versus nondegraded conditions, and (c) that older adults did not demonstrate negative priming for undistorted stimuli, the evidence suggests that negative priming in the degraded target condition most likely reflects the operation of a back-ward-acting episodic retrieval process rather than a forward-acting inhibitory mechanism.

One concern regarding the conclusions of the Kane, May, et al. (1995) studies, however, is that degrading the test targets served to increase response times, raising the possibility that the negative priming seen for younger and older adults was some-how an artifact of slower reaction times. However, older adults typically respond more slowly than younger adults in negative priming studies (e.g., Hasher et al., 1991; Kane, Hasher, et al., 1994). If negative priming is contingent on slower responses only, it is unclear why younger adults, who generally respond significantly faster than older adults, consistently demonstrate negative priming, whereas older adults do not.

As well, a study by Kane, May, et al. (1995, Experiment 2) addresses the relation between overall speed and negative priming, which provides further evidence for episodic retrieval as the main source of negative priming effects seen for older adults. In this study, stimulus exposure durations were manipulated across prime and trials in a between-subjects design. Some older adults saw brief (150 ms) primes and tests, some saw long (300 ms) primes and brief (150 ms) tests, and some saw brief (150 ms) primes and long (300 ms) tests.

lf, as we suggest, episodic retrieval is elicited only by specific experimental manipulations, certain predictions should hold for these conditions: First, if episodic retrieval is *induced by* processing difficulties on the *test,* then older adults might be expected to show negative priming only when the stimulus exposure durations on the test trial are brief, making the target difficult to process. Second, if on some occasions negative priming results from the successful retrieval of prior episodes, then the accessibility of the information stored with those prior episodes should impact the amount of negative priming observed whenever participants are induced to retrieve. Thus, more negative priming should occur when prime trials are long rather than short because the former likely permits more time to en-code the distractor than the latter. Together, these two predictions suggest a specific pattern of results: Most negative priming should occur with long-prime—brief-test trials (the prime trial offers the most information and the test trial offers the least), moderate negative priming should occur with brief-prime—brief-test trials, and the least negative priming, if any, should occur with brief-prime—long-test trials. Indeed, the data were perfectly in line with these predictions: Older adults showed re-liable and large (25 ms) negative priming effects in the long-prime—brief-test condition, significant yet reliably smaller negative priming (8 ms) in the brief-prime—brief-test condition, and no significant negative priming (2 ms) in the brief-prime—long-test condition. (Other research has shown no negative priming for older adults when the prime and test are both long; Kane, Hasher, et al., 1994, Experiment 1.)

A critical difference between the prime—test exposure duration experiment and the visual degradation experiment is the effect that shortening stimulus exposure duration had on overall response times: Unlike the degradation condition, which in-creased response times, brief stimulus exposure durations had no effect on response times. These data thus suggest that the critical variable for producing enhanced negative priming is not an increase in overall response time but an increase in the difficulty of target identification on test trials.

The findings from these studies suggest that creating processing difficulties on test trials, for example, through stimulus degradation or exposure duration constraints, can induce both younger and older adults to retrieve prior episodes. This retrieval results in enhanced negative priming as the result of conflict between the currently required response and the previously required response. Retrieval induced by aspects of the test trial will be most successful when the prime trial is distinctive and its processing is not otherwise impeded. Thus, episodic retrieval can, in some instances, be the primary determinant of negative priming through a response code conflict between successive episodes. The findings are also consistent with the notion that not all negative priming is due to retrieval-induced conflicts in response codes.

Contexts That Induce Episodic Retrieval

We now consider additional variables that might induce or encourage participants to use episodic retrieval on test trials. Specification of these variables is critical for determining when negative priming reflects the action of an inhibitory mechanism and when it may also, or instead, reflect the outcome of episodic retrieval processes.

According to the episodic retrieval theory, successful retrieval enhances performance (i.e., speed response, improve accuracy, or both) when the previous response requirement for a given stimulus matches its current response requirement. Within the context of negative priming tasks, this should occur whenever the target repeats on successive trials. Thus, when a significant proportion of all trials are repeated target, repeated distractor, or both types of trials, one might expect generally heightened rates of episodic retrieval, resulting in facilitated performance on repeated target trials and in impeded performance on negative priming trials.

Indirect evidence suggests episodic retrieval processes may function in experiments that include repeated target trials. Experiments that contain a significant proportion of repeated target trials (e.g., Allport et al., 1985, Experiments 4 and 5; Lowe, 1979, 1985, Experiments 1-3; Tipper, 1985, Experiment 3; Tipper & Driver, 1988) generally show larger negative priming effects than those that do not contain repeated target trials (e.g., Hasher et al., 1991; Kane, Hasher, et al., 1994; Neill, 1977; Neill et al., 1992; E. Neumann & DeSchepper, 1991, Experiment 1; but see E. Neumann & DeSchepper, 1991, Experiment 2 for an exception).

In fact, the inclusion of repeated targets across trials in a study by Sullivan and Faust (1993) may explain their report of negative priming in older adults, who elsewhere (e.g., Hasher et al., 1991; Kane, Hasher, et al., 1994; McDowd & Oseas-Kreger, 1991; Stoltzfus et al., 1993; Tipper, 1991) did not show the effect. Sullivan and Faust attributed the negative priming shown by older adults in their experiment to the fact that they used overlapping pictures as stimuli. However, others have used over-lapping letters (McDowd & Oseas-Kreger, 1991) and spatially separated pictures (Tipper, 1991) and have not found negative priming for older adults. The major difference between the set of studies that do not show negative priming for older adults and the Sullivan and Faust study is that only the latter study included repeated target trials, which may have induced episodic retrieval.

A recent study by Kane, May, et al. (1995, Experiment 3) speaks to this issue. Recall that Kane, Hasher, et al. (1994, Experiment 1) tested older adults in an experiment that did not contain any repeated target trials (older adults did not show negative priming). Their procedure was then modified to match Sullivan and Faust's (1993), such that 40% of the filler trials were replaced with repeated target trials. In this new context, older adults did show significant negative priming. Moreover, those adults who showed the greatest negative priming also demonstrated the greatest repeated target benefit, as would be expected if the adults were retrieving prior episodes on many trials. These findings suggest that older adults will en-gage in episodic retrieval when repeated target trials are included in the experimental context and, as a result of the com-petition between response codes, will demonstrate significant negative priming.[5]

The data reviewed thus far suggest that two variables, poor stimulus quality (through perceptual degradation or limited exposure) and an experimental context that includes many repeated target trials, induce an episodic retrieval process. A third variable, suggested by positive priming studies, is the use of lexical decision or yes-or-no response tasks rather than naming tasks. Evidence from positive priming studies indicates that lexical decision tasks are much more susceptible to the operation of *postlexical processing* (e.g., retrieval of information from a previous trial) than are naming tasks (e.g., Forster, 1979; Neely, 1991; Theios & Muise, 1977; West & Stanovich, 1982). For example, only lexical decision tasks demonstrate effects of syntactic and backward associations (Seidenberg, Waters, Sanders, & Langer, 1984) and are affected by manipulations of the pro-portion of different trial types (Neely, 1991).

In parallel with the positive priming literature, in negative priming one might expect to find a greater impact of postlexical processing when lexical decision or yes-or-no decision-type tasks are used rather than a naming task. Episodic retrieval can be thought of as a postlexical process because it is initiated after lexical access (or identity coding) and it encourages contextual information (i.e., stimuli from a previous trial) to affect the response to the current trial. As a postlexical process, then, episodic retrieval should be more likely to be engaged by lexical decision (or other yes-or-no decision) responses than by naming, creating larger negative priming effects than are seen with naming.

Only a handful of negative priming studies have used yes-or-no response tasks, but the data from those studies are consistent with the suggestion that episodic retrieval is indeed engaged. Neill and Valdes (1992) used a yes-or-no letter-matching task in their study. The negative priming effects in their study were quite substantial at the 500-ms RSI (—65 ms) and then diminished to a steady state (18 ms6) for up to 8,000 ms between trials. This decline in negative priming is quite consistent with predictions from an episodic retrieval perspective because at this shortest RSI, the antecedent trial should be maximally distinctive from other trials, heightening the success of retrieval and creating the opportunity for maximal conflict in response codes.

To date only two studies have used a lexical decision task in the context of negative priming studies (Hoffman & MacMillan, 1985; Yee, 1991). Yee had participants make lexical decisions to letter strings on nonconflict-type test trials (i.e., there were no distractors present). Recall that in other studies using only nonconflict stimuli, participants failed to demonstrate negative priming and in some instances even showed facilitation (e.g., Lowe, 1979; Tipper & Cranston, 1985). Yee's findings are noteworthy in that significant negative priming was found in the absence of selection demands (see also Hoffman & MacMillan, 1985, for similar findings). Again, in parallel with positive priming, it is likely that the maintenance of negative priming in these studies reflects the fact that the lexical decision task used induced episodic retrieval, which set up response code competition and consequently slowed responding on negative priming trials.

To our knowledge, there are currently no data that speak directly to the proposal that yes-or-no decision tasks allow or in-duce episodic retrieval processes to influence negative priming. Without such systematic comparison of yes-or-no and lexical decision versions of negative priming tasks with naming versions, the comparisons that are possible on the basis of the existing literature are all fully consistent with the view that episodic retrieval can induce negative priming.

In summary, considerably enhanced negative priming for younger adults and reliable negative priming for older adults occurs in at least three experimental contexts: (a) those in which target identification is difficult on test trials, (b) those containing a large proportion of repeated target trials, and (c) those involving yes-or-no decision tasks. We propose that in these experimental contexts, negative priming is primarily determined by the operation of a backward-acting episodic retrieval mechanism, which results in response code conflict, rather than by a forward-acting inhibitory process.

Reconsideration of Conclusions Regarding Inhibition

Given that negative priming is a multiply determined effect, the validity of the conclusions regarding inhibitory processing require some reevaluation. We briefly reconsider these conclusions, examining those studies in which only inhibition is operating to produce negative priming. To this end, we consider experiments that (a) permit full, unobstructed identification of test targets, (b) do not include conditions (such as repeated target) in which episodic retrieval would be advantageous, and (c) do not use decision-type tasks that afford postlexical processing. To preview, this reanalysis indicates that our earlier conclusions regarding inhibitory functioning remain essentially unchanged, and in some instances the omission of episodic retrieval studies enables the resolution of discrepancies in the data.

With respect to the time course of negative priming, our re-consideration reveals a clear and consistent pattern: Negative priming develops over time (Lowe, 1985; Neill, 1977; Neill & Westberry, 1987; E. Neumann & DeSchepper, 1992) and persists for several seconds (Hasher et al., 1991; Stoltzfus et al., 1993; Tipper, Weaver, Cameron, et al., 1991), even during further processing (Tipper, Weaver, Cameron, et al., 1991). Only in those studies in which episodic retrieval may be functioning (i.e., Neill & Valdes, 1992) did negative priming show a decay over time.

Reconsideration of the relation between negative priming and interference replicates the previous conclusion that there is no systematic pattern between these measures: Some studies demonstrate an inverse relation between negative priming and interference (Allport et al., 1985, Experiments 6-8; Beech, Baylis, Smithson, et al., 1989; Kane, Hasher, et al., 1994; McDowd & Oseas-Kreger, 1991; Tipper et al., 1989), whereas others show a positive relation (Neill, Valdes, & Terry, 1995; E. Neumann, 1993; Valdes, 1993), and still others show no relation (Beech, Baylis, Smithson, et al., 1989, Experiment 3; Beech & Claridge, 1987; Beech, Powell, et al., 1989; Driver & Tipper, 1989; Stoltzfus et al., 1993; Tipper et al., 1988). Furthermore, examination of only those studies believed to involve episodic retrieval similarly fails to illuminate a consistent relation between negative priming and interference, with evidence for a negative relation (Sullivan & Faust, 1993; Tipper & Baylis, 1987), a positive relation (Neill & Lissner, 1988), and no relation (Yee, 1991) between the two measures.

As well, conclusions concerning the level at which inhibition operates do not change when those studies that may involve episodic retrieval are excluded from analyses: Negative priming maintains across physical changes in stimuli from prime to test trials (e.g., Allport et al., 1985, Experiment 4; Driver & Tipper, 1989, Experiment 3) and across changes in response mode from prime to test trials (Tipper et al., 1988), indicating that inhibition functions at a central, abstract level to block semantic representations from any response output.

Reanalysis of the data on special populations clearly indicates that children, older adults, and schizophrenic patients suffer deficits in identity inhibitory processing (e.g., Beech, Powell, et al., 1989; Hasher et al., 1991; McDowd & Oseas-Kreger, 1991; Tipper et al., 1989) and, furthermore, that children (Tipper & McLaren, 1990) and older adults show preserved inhibitory processing for location information (Connelly & Hasher, 1993). These data are in line with our initial assertions that (a) identity inhibitory functioning is impaired in certain groups and (b) separate inhibitory systems may exist for identity and location information.

Finally, our reconsideration reveals that inhibition is a flexible, adaptive mechanism, susceptible to shifts in participants' expectations and variations in experimental context (Allport et al., 1985, Experiment 9; Hasher et al., 1991; Neill & Westberry, 1987; Stoltzfus et al., 1993; Tipper & Cranston, 1985, Experiment 3).

In summary, our initial conclusions regarding the nature and function of inhibition remain, and in some instances are strengthened, when those studies in which episodic retrieval is thought to contribute to the negative priming effect are excluded from consideration.

Summary and Conclusions

Recent interest in the negative priming effect stems largely from the assumption that it serves as a window into a fundamental mechanism of attention and inhibition and to the con-sequences for cognition when inhibition malfunctions. A critical review of the literature suggests that, at least under some experimental circumstances, these assumptions are viable. On the basis of experiments that do not engage episodic retrieval, and so show the consequences of inhibition, the following observations can be made. First, inhibition is not evident immediately after selection but requires time to develop and then endures for several seconds, even during further processing of other information. Second, inhibition shows no consistent relation with interference, a measure used to assess distraction during current selection. Together, these findings suggest that inhibition does not aid current selection but operates after selection is complete to maintain the distinction between goal-relevant and goal-irrelevant information, once that distinction has been established. Third, inhibition is not tied to specific stimuli, response types, or even response modes but functions at a central, abstract level to block semantic representations from any response output. Fourth, certain populations such as children, older adults, and schizophrenic patients fail to show negative priming for identity, suggesting that these groups suffer deficient identity inhibitory processing. Furthermore, preserved location negative priming for children and older adults suggests that two separate inhibitory systems may exist, one for identity and one for location, and that location inhibition is preserved across the life span. Insofar as studies of location and identity inhibition overlap, the two mechanisms seem to have similar parameters, with the exception of their development over the life span.

Finally, inhibition is a relatively flexible mechanism, adapting to shifts in participants' strategies induced by changes in experimental context.

Whereas a single-mechanism account of negative priming would be parsimonious, the evidence does not permit the conclusion that negative priming always reflects only inhibition. Rather, just as positive priming reflects two processes, so does negative priming. The second mechanism responsible for negative priming is episodic retrieval. Our review presents evidence suggesting that episodic retrieval is induced when processing difficulties (e.g., target degradation) occur on test trials, when the experimental context makes such a process advantageous (e.g., repeated target trials are included), or when the response task encourages postlexical processes.

The fact that negative priming is multiply determined has important theoretical implications. First, it should caution all researchers who use negative priming as a tool for investigating inhibitory mechanisms. Robust negative priming effects do *not* necessarily indicate the action of inhibition in selective processing. Thus, studies that explore the nature of inhibition through negative priming measures without respect to the issues of dual determination may arrive at inappropriate conclusions, attributing results to inhibition when they may be due either to inhibition or to episodic retrieval.

Furthermore, investigators who use negative priming as an index of inhibitory functioning in special populations must be aware of and avoid the conditions in which episodic retrieval may operate to produce negative priming. Otherwise, evidence of negative priming in these populations may reflect an episodic retrieval process that induces response code conflict rather than spared inhibitory functioning. At this time then, investigators interested in inhibition as an attentional process or in individual or group differences in inhibition have a couple of strategies open to them. First, investigators could test participants only under conditions that are unlikely to induce episodic retrieval by using the following guidelines: (a) Use stimulus displays that are sufficiently long for participants to identify targets fully; (b) use response requirements, such as naming, that do not engage postlexical processing; and (c) include only conditions in which there is no particular benefit that will accrue from episodic retrieval *(in* particular, omit repeated target trials). Such conditions are likely to permit the observation of inhibitory attentional mechanisms or the failure of those mechanisms (as evidence suggests is the case for older adults; see Kane, Hasher, et al., 1994). An alternative would be for investigators to observe participants both under the conditions that avoid inducing episodic retrieval and conditions that are likely to induce episodic retrieval. Such an approach not only allows more accurate conclusions regarding the bases of group differences in negative priming but might also resolve extant controversies in the literature, such as the correlation (or the lack thereof) between negative priming and interference measures.

Continued investigation of negative priming under conditions in which inhibition is presumed to operate is critically important because, to date, negative priming is the best available index of inhibitory attentional processes. In turn, the role of inhibition in determining a wide variety of other cognitive behaviors—including the ability to establish coherent thought and speech streams, the ability to comprehend language, and the ability to remember efficiently—seems increasingly compelling (Dagenbach & Carr, 1994; Gernsbacher & Faust, 1991; Hasher & Zacks, 1988; Logan, 1994; Stoltzfus, et al., in press; Zacks & Hasher, 1994), giving impetus to continued exploration of the importance of basic attentional processes to general cognitive functioning.

Notes

1 In some cases, participants respond to the location rather than the identity of the stimulus. Recent research suggests that *location-based* tasks comprise a distinct class of negative priming tasks. These are discussed later.

2 After this article was accepted for publication, we became aware of another review of the negative priming literature (Fox, in press). We highlight later in the text where our two reviews draw similar and different conclusions.

3 That negative priming persists over changes in stimulus features (such as case) and across semantic associates (such as *cat to dog)* precludes the possibility that the mechanism responsible for identity negative priming functions early in the stimulus processing sequence. If distractors were filtered from attentional processing on the basis of their color or location, negative priming for semantic information would be impossible. However, an anonymous reviewer has suggested that inhibition may also function at an early stage of processing, but that reaction time methods are insensitive to such early selection phenomena. The reviewer noted that tachistoscopic methods (e.g., Santee & Egeth, 1982), which are more sensitive to input processes, may be useful in future work to more effectively address issues of early selection in negative priming. The early versus late selection issues are also addressed in the section *Individual Differences of Negative Priming.*

4 It should be noted that the episodic retrieval view closely resembles an earlier theory, referred to as the code coordination hypothesis (Keele & Neill, 1978; Lowe, 1979). The two theories differ with respect to the source of the conflict thought to be responsible for negative priming. For episodic retrieval, the conflict results when two different response tags are linked with one stimulus. For code coordination, the conflict results when two different physical codes (such as color) are associated with the same stimulus. In a direct test of the code coordination view, Tipper and Cranston (1985, Experiment 4) found negative priming when there was no conflict in stimulus color codes across trials.

5 Again, the question arises of whether schizophrenic patients show similar effects. Recent data indicate that, in fact, nonpathological schizotype adults do not show negative priming in an experimental context with a significant number of repeated target trials (Beech, Baylis, Tipper, McManus, & Agar, 1991). These findings are consistent with the recent claim that schizophrenia is marked by an inability to use contextual information during processing (Cohen & Servan-Schreiber, 1992), and they suggest that a critical goal of future work in this area

6 This value is consistent with the larger literature showing effects in the 10-25 ms range.

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Appendix

Stimuli and Response Tasks Used to Demonstrate Negative Priming

Stimuli

1. Stroop color words: Beech, Agar, & Baylis, 1989; Beech, Baylis, Smithson, & Claridge, 1989; Beech & Claridge, 1987; Beech, Powell, McWilliam, & Claridge, 1989; Dalrymple-Alford & Budayr, 1966; Effier, 1977a, 1977b; Enright & Beech, 1990; Laplante, Everett, & Thomas, 1992; Lowe, 1979,1985; Neill, 1977; Neill & Westberry, 1987; Tipper, Bourque, Anderson, & Brehaut, 1989.

2. Pictures: Allport, Tipper, & Chmiel, 1985; Gernsbacher & Faust, 1991; Sullivan & Faust, 1993; Tipper, 1985,1991; Tipper & Driver, 1988; Tipper, Weaver, Cameron, Brehaut, & Bastedo, 1991.

3. Letters: Allport et al., 1985; Connelly & Hasher, 1993; Hasher, Stoltzfus, Zacks, & Rypma, 1991; McDowd & Oseas-Kreger, 1991; Neill, Lissner, & Beck, 1990; Neill & Valdes, 1992; E. Neumann & DeSchepper, 1991,1992; Stoltzfus, Hasher, Zacks, Ulivi, & Goldstein, 1993; Tipper &Cranston, 1985; Tipper, MacQueen, & Brehaut, 1988.

4. Words: Beech, Baylis, Tipper, McManus, & Agar, 1991; Carlson, Hasher, & Linville, 1993; Hoffman & MacMillan, 1985; Kane, Hasher, Stoltzfus, Zacks, & Connelly, 1994; Kane, May, Hasher, Rahhal, & Stoltzfus, 1995; McCloskey, Felio, Rosser, & Neumann, 1992; Tipper & Driver, 1988; Yee, 1991.

5. Digits: Driver & Tipper, 1989; Greenwald, 1972.

6. Novel shapes: DeSchepper & Treisman, 1991.

7. Three-dimensional objects: Tipper, Lortie, & Baylis, 1992.

Response Tasks

1. Naming: Allport et al., 1985; Beech, Agar, & Baylis, 1989; Beech, Baylis, Smithson, & Claridge, 1989; Beech et al., 1991; Beech, Powell, McWilliam, & Claridge, 1989; Dalrymple-Alford & Budayr, 1966; Hasher et al., 1991; Kane, Hasher, Stoltzfus, Zacks, & Connelly, 1994; Kane, May, Hasher, Rahhal, & Stoltzfus, 1995; Neill, 1977; Stoltzfus et al., 1993; Sullivan & Faust, 1993; Tipper, 1985,1991; Tipper & Cranston, 1985; Tipper et al., 1989.

2. Lexical decision: Hoffman & MacMillan, 1985; McCloskey et al., 1992; Yee, 1991.

3. Same-different matching: Neill, 1979; Neill et al., 1990; Neill & Valdes, 1992.

4. Counting: Driver & Tipper, 1989.

5. Manual keypress: Neill & Westberry, 1987; Tipper et al., 1988.

6. Reaching: Tipper et al., 1992.