

Dual Mechanisms of Negative Priming

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Abstract:

Three experiments examined whether negative priming is a dually determined effect produced by inhibitory mechanisms and by a memorial process. Younger adults (Experiment 1) and older adults (Experiments 1-3) were tested in procedures that varied the likelihood of inducing retrieval of the prior trial. This was done by making test-trial target decoding difficult (Experiments 1 & 2) or by making prior information useful on some nonnegative priming trials (Experiment 3). Younger adults demonstrated negative priming under retrieval and nonretrieval conditions, with patterns of performance indicating different sources of negative priming effects. Older adults showed negative priming only under retrieval-inducing conditions, consistent with the view of deficient inhibitory mechanisms for older adults. The data suggest that contextual variables critically determine whether negative priming is largely due to inhibition or to episodic retrieval.

Article:

As evidenced by two recent volumes dedicated entirely to inhibitory theories of attention, memory, and language (Dagenbach & Carr, 1994a; Dempster & Brainerd, 1995), the role of inhibition in cognitive functioning is a current focus of investigation in mainstream psychology. Indeed, inhibitory mechanisms are now a prominent explanatory construct in a number of cognitive domains, including selective attention (e.g., Navon, 1989a, 1989b; Tipper, 1985), memory retrieval and forgetting (e.g., Anderson & Bjork, 1994; Bjork, 1989; Brown, 1991; Dagenbach & Carr, 1994b; Nickerson, 1984), language processing (e.g., Gernsbacher & Faust, 1991; Simpson & Kang, 1994), and cognitive development over the life span (Dempster, 1992; Hasher & Zacks, 1988; Zacks & Hasher, 1994). In addition, inhibitory mechanisms operating in the service of goals are critical to at least one general theory of cognition that ties language processing and memorial consequences to efficient inhibitory control over the contents of working memory (Hasher & Zacks, 1988; Hasher, Zacks, & May, in press; Zacks & Hasher, 1994).

The heightened interest in inhibitory theories of cognition has in part been stimulated by experiments using the negative priming procedure, currently regarded as the best available index of inhibitory attentional processing (for reviews see Fox, 1995; May, Kane, & Hasher, 1995; Neill, Valdes, & Terry, 1995). In a typical negative priming task, participants are presented with a list of trials consisting of paired displays, and on each display they must selectively respond to a target stimulus (e.g., a red word) while ignoring a distractor stimulus (e.g., a green word). On critical negative priming trials, participants respond to a target on one display (called the *test* display) that had served as a distractor on the preceding display (called the *prime* display; see Figure 1). Responses on such trials are slower (and sometimes less accurate) than are responses on control trials, in which participants respond to a test target that had not appeared on the prime display (e.g., Dalrymple-Alford & Budayr, 1966; Lowe, 1979; Neill, 1977; Tipper, 1985). This slowing is termed the *negative priming effect* (Tipper & Cranston, 1985), and recent intensive investigation has revealed its robustness across a variety of stimuli and response tasks (see May et al., 1995; Neill et al., 1995).

The dominant explanation for the negative priming effect has been an inhibitory process, thought of as an attentional mechanism that blocks the representation of a distractor from access to response systems (e.g., Neill

& Westberry, 1987; Tipper & Cranston, 1985). If that distractor subsequently appears as a target on the test display, the inhibition will take time to dissipate, evidenced by delayed (and some-times error prone) responding. In this view, inhibition is a forward-acting process, in that the inhibition of a distractor on a prime display has downstream consequences for responding to that item should it appear as the target on a test display. In this way, inhibition may serve to prevent recently rejected distractors from immediately returning to the focus of attention (Stoltzfus, Hasher, Zacks, Ulivi, & Goldstein, 1993; Tipper, Weaver, Cameron, Brehaut, & Bastedo, 1991), thus enabling selected targets the small amount of time needed to recruit the activation required to establish coherent chains of thought and action.

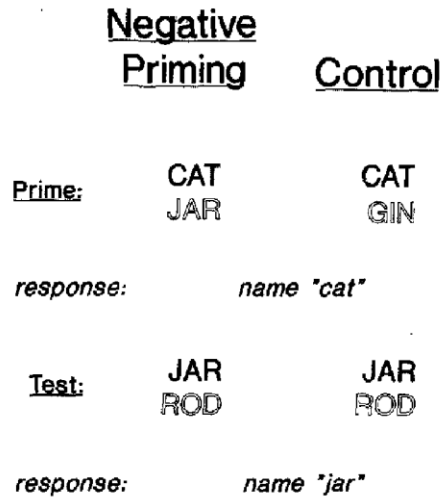


Figure 1. Example of hypothetical negative priming and control trials. Targets are printed in black; distractors are printed in white.

There is strong evidence in the negative priming literature that inhibition is largely responsible for the negative priming effect (e.g., Allport, Tipper, & Chmiel, 1985; Driver & Tipper, 1989; Neill & Westberry, 1987; Neumann & DeSchepper, 1991; Tipper & Cranston, 1985). Indeed, the inhibitory framework provides the best explanation for nearly all of the findings in the extant negative priming literature (May et al., 1995; Tipper & Milliken, 1994). For example, the inhibitory view accounts for data indicating that negative priming (a) takes time to accrue (e.g., Lowe, 1979; Neill & Westberry, 1987), (b) maintains across intervening trials (DeSchepper & Treisman, 1991; Tipper et al., 1991), (c) occurs across changes in both the features of stimuli and the response modes (Driver & Tipper, 1989; Tipper & Driver, 1988), and (d) is susceptible to changes in participants' strategies (see May et al., 1995, for a review). Furthermore, the failure of certain populations to show negative priming, such as children (Tipper, Bourque, Anderson, & Brehaut, 1989), older adults (e.g., Hasher, Stoltzfus, Zacks, & Rypma, 1991; McDowd & Oseas-Kreger, 1991; Tipper, 1991), and patients with schizophrenia (e.g., Beech, Powell, McWilliam, & Claridge, 1989; Laptante, Everett, & Thomas, 1992), is consistent with demonstrations elsewhere in the literature that these groups suffer deficits in attentional inhibition (e.g., Doyle, 1973; Frith, 1979; Gray, Feldon, Rawlins, Hemsley, & Smith, 1991; Hasher & Zacks, 1988; Zacks & Hasher, 1994).

However, a recent set of data has posed problems for the inhibitory framework, and as a result an alternative, memory-based view of the mechanism underlying negative priming has been advanced (Neill & Valdes, 1992; Neill et al., 1995; Neill, Valdes, Terry, & Gorfein, 1992; for related views see also Lowe, 1979, 1985; Park & Kanwisher, 1994). According to this explanation for the negative priming effect (based on Logan's, 1988, theory of automaticity), the presentation of a familiar stimulus automatically evokes the retrieval of recent episodes involving that stimulus. Each retrieved episode includes information (or "tags") about the stimulus and its attributes, for example, its meaning, its color, its location, and, critically for our purposes, the response that was made to it. For example, presentation of the word jar as a target causes the retrieval of the most recent episode involving jar. If jar served as a distractor on the previous trial, then an ignore-it tag is retrieved. Once

retrieved, this ignore-it tag is compared with the current tag, or response requirement (i.e., name it) for that stimulus. If the retrieved response tag does not match the current response tag (as in the present example of a negative priming trial), responding is impeded until the ambiguity can be resolved. Note also that by this logic (see Logan, 1988), if the previous tag and the current tag match (as would be the case if an item appeared as a target on both prime and test displays), responding should be facilitated.

According to the episodic retrieval view, then, negative priming is caused by the response code conflict that results when the response tag for the current target stimulus (*name it*) is compared with the tag retrieved from the previous display (*ignore it*), in which the same stimulus served as a distractor. Resolution of this conflict delays response, resulting in the negative priming effect. Note that unlike inhibition, which acts in a forward direction to block a prime distractor from future access to a response, episodic retrieval acts in a backward direction: The presentation of a stimulus on the test display evokes the retrieval of a previous episode with that item. Any discrepancy in the response codes regarding the role of that item (as a target or as a distractor) then impedes response. For the episodic retrieval view, presentation of an item as a distractor has no consequence unless that item reappears on a subsequent trial, at which point its earlier representation, if successfully retrieved, will slow responding.

Initial support for the episodic retrieval view came from experiments examining whether negative priming effects decrease in size as the intervals between the prime-display response and the test-display onset (or response-to-stimulus intervals; RSIs) increase. Current data indicate that negative priming does not decrease when RSIs are manipulated between subjects (Hasher et al., 1991; Stoltzfus et al., 1993; Tipper et al., 1991), but it does decrease if RSIs are manipulated randomly within subjects (Neill & Valdes, 1992; Neill et al., 1992). That is, when participants are exposed to trials that all have the same RSI, negative priming effects are not influenced by how long or short that particular RSI happens to be; however, when participants are exposed to some trials with long RSIs and some trials with short RSIs, more negative priming is seen for the short RSI trials (but see Hasher, Zacks, Stoltzfus, Kane, & Connelly, 1996).

Although the above data are not easily accommodated by the inhibition hypothesis (in which a forward-acting mechanism operates equivalently on each prime-display distractor), they do fit well with the episodic retrieval view. A critical assumption of episodic retrieval is that previous episodes are retrieved with varying success rates (Neill & Valdes, 1992; Neill et al., 1992). Because successful retrieval is necessary for response conflict (and hence for negative priming) to occur, the amount of negative priming observed is not constant; rather, negative priming depends largely on the probability of successfully retrieving a prior episode. One variable proposed to influence the probability of retrieving a given episode is the temporal discriminability of that episode from prior episodes (Baddeley, 1976). Trials that are temporally distinct from other trials have a greater probability of retrieval and thus should result in more negative priming.

In a between-subjects design, the RSI is constant for a given participant; thus, all trials have equivalent temporal discriminability, regardless of the specific RSI that is used. Negative priming should therefore not vary across RSIs in a between-subjects design, and indeed it does not (Hasher et al., 1991; Stoltzfus et al., 1993; Tipper et al., 1991). In a within-subjects design, however, the RSI varies across trials, and thus trials succeeded by short RSIs are more discriminable from prior trials than are those succeeded by long RSIs. Trials that have greater temporal discriminability are more easily retrieved, and thus greater negative priming should occur with short RSIs rather than with long RSIs in a within-subjects design, which is the pattern demonstrated by Neill and colleagues (Neill & Valdes, 1992; Neill et al., 1992; but see Hasher et al., 1996).

There is, then, preliminary evidence that episodic retrieval may operate in some circumstances to produce negative priming. Although an inhibitory view of negative priming cannot account for the pattern of data seen in between- versus within-subjects manipulations of RSI, there is, as noted earlier, compelling evidence that inhibition produces negative priming in a number of experimental contexts (see Houghton & Tipper, 1994; May et al., 1995; Tipper & Cranston, 1985; Tipper & Milliken, 1994). The aims of our research were therefore to (a) explore whether negative priming may be (at least) dually determined, produced both by inhibition and episodic

retrieval; (b) determine whether or not specific predictions that necessarily follow from the episodic retrieval view are tenable (given that there is, as yet, only limited empirical evidence for episodic retrieval in negative priming); and (c) assess whether the particular mechanisms responsible for producing negative priming may critically depend on some con-textual details of the experiment.

A preview of our findings indicates that both inhibition and episodic retrieval can indeed produce negative priming and that specific experimental circumstances determine which is the primary source. In contrast to initial suggestions that episodic retrieval automatically occurs in all contexts to produce negative priming (Neill & Valdes, 1992; Neill et al., 1992), we argue that episodic retrieval is a process that is elicited only by specific experimental circumstances (see Logan, 1988). Although episodic retrieval does not occur in every context, we propose that when elicited, episodic retrieval is a stimulus-driven process that occurs automatically and without intention. Thus, on the basis of our work and of the findings in the larger literature, we propose that negative priming is produced by an attentional inhibitory mechanism except in those instances in which episodic retrieval is induced by the experimental context.

The view that negative priming is dually determined has its analogue in the literature on positive semantic priming. *Positive priming* refers to facilitated responding seen in naming a target word, such as *chair*, when it is preceded by a related prime word, such as *table*, relative to when it is preceded by an unrelated word, such as *lettuce*. Priming effects are generally attributed to a spreading activation process: Activation of a prime word spreads forward in time through the semantic network to aid the identification of a target word (see, e.g., McNamara, 1992, 1994; Neely, 1977). However, certain experimental contexts encourage or enable positive semantic priming to be influenced by retrieval processes. For example, priming is greatly enhanced when the perceptual display makes it difficult to identify the target item on the test display (Becker & Killion, 1977; Neely, 1991; Stanovich & West, 1979). Under these circumstances, people retrieve the antecedent prime item to aid in the identification of the current target (Whittlesea & Jacoby, 1990). This retrieval results in the unitization of the prime and the target as memory cues (Ratcliff & McKoon, 1988), which in turn magnifies the priming effect. Thus, whereas spreading activation underlies positive priming under standard visual conditions (e.g., McNamara, 1992, 1994), episodic retrieval causes positive priming under degraded visual conditions (Whittlesea & Jacoby, 1990).

Direct evidence that stimulus degradation induces retrieval comes from a series of experiments by Whittlesea and Jacoby (1990). They examined repetition priming by using word triplets, with the task being to name the third, final word. On critical trials, the first word (the prime) and the third word (the target) were identical (e.g., *green-plant—green*). The second, interpolated, word was either semantically related or unrelated to the prime and the target, and it was either degraded or nondegraded. As predicted by episodic retrieval, target naming was fastest when the preceding interpolated word was related to the prime and test words and when it was visually degraded. This is because degrading the interpolated word induced the retrieval of the prime word, allowing the semantically related prime to then participate in the identification of the subsequent test word. It is important to note that spreading activation accounts of priming actually make the opposite prediction:

Degrading the interpolated word delays its identification, which in turn allows greater decay of the prime word's activation, leaving less activation from the prime (and therefore less repetition priming) at target presentation.

Analogous to positive priming, in which, depending on the experimental context, both forward-acting processes (i.e., spreading activation) and backward-acting processes (i.e., episodic retrieval) dually determine priming, negative priming may also be dually determined, with both forward-acting and backward-acting mechanisms (inhibition and episodic retrieval, respectively). On this basis, we predicted that under standard, nondegraded viewing conditions, negative priming would largely reflect the action of a forward-acting inhibitory mechanism. By contrast, under degraded stimulus conditions, negative priming would primarily reflect the consequences of antecedent retrievals that in this situation result in a conflict between the current response requirements (*name it*) and the previous response code (*ignore it*). Finally, because contexts that induce episodic retrieval elicit larger positive priming effects than those that do not (e.g., Becker & Killion, 1977; Neely, 1991; Stanovich &

West, 1979), we predicted that negative priming effects would be larger in episodic-retrieval-inducing conditions than in standard, inhibition-inducing conditions.

In these experiments we included both standard conditions and visually degraded conditions to contrast negative priming effects under circumstances that should, rather than should not, induce episodic retrieval. As a further indicator of whether inhibition or episodic retrieval is responsible for negative priming, we also tested older adults because of the strong suggestion in the literature that inhibitory mechanisms diminish in efficiency with age (*see* Hasher & Zacks, 1988; Hasher et al, in press; Zacks & Hasher, 1994). Indeed, across a wide array of experimental paradigms, older adults are generally less able than younger adults to inhibit or suppress irrelevant or distracting information. For example, relative to younger adults, older adults were more susceptible to visual distraction when reading (Carlson, Hasher, Connelly, & Zacks, 1995; Connelly, Hasher, & Zacks, 1991; Shaw, Toffle, & Rypma, 1992), were less able to abandon irrelevant or inappropriate interpretations of text (Hamm & Hasher, 1992; Hartman & Hasher, 1991; Stoltzfus, 1992), produced more off-goal circumlocutions in speech (Arbuckle & Gold, 1993), and showed heightened intrusion rates in recall (Gerard, Zacks, Hasher, & Radvansky, 1991; Giambra & Howard, 1994; Zacks & Hasher, 1994; Zacks, Radvansky, & Hasher, 1996). Furthermore, findings from the negative priming literature also generally support the notion of age-related declines in inhibitory functioning: Older adults failed to show negative priming for the identity of a target under standard viewing conditions in a number of studies (Connelly & Hasher, 1993; Hasher *et al.*, 1991, Experiments 1 & 2; Kane, Hasher, Stoltzfus, Zacks, & Connelly, 1994, Experiments 1 & 2; Kwong See, Tipper, Weaver, & Ryan, 1994, Experiment 1; McDowd & Oseas-Kreger, 1991; McDowd, Oseas-Kreger, & Filion, 1995; Oseas-Kreger & McDowd, 1992; Stoltzfus *et al.*, 1993). Note that in contrast to studies in which selection was based on target identity, those studies in which selection was based on target location failed to show age-related deficits in inhibition (Connelly & Hasher, 1993; McDowd, Filion, & Baylis, 1992; Simone & Baylis, in press), suggesting that unlike inhibition of identity, inhibition of location may be preserved across the life span.

Thus, given the considerable evidence from the cognitive aging literature for age deficits in inhibition, we predicted that older adults would not show negative priming in experimental circumstances in which only inhibition was operating. However, in situations that have been shown elsewhere to induce episodic retrieval, older adults, like younger adults, were expected to show negative priming, just as older adults have shown comparable increases to younger adults in positive priming tasks when stimuli were degraded (Madden, 1988, 1992). In addition, the inclusion of older adults in this study allowed us to resolve some current discrepancies in the negative priming literature regarding age differences in negative priming; our aim was to demonstrate that recent reports of equivalent negative priming for younger and older adults reflect episodic retrieval rather than inhibition (e.g., Sullivan & Faust, 1993; Sullivan, Faust, & Balota, 1995).

In the first experiment we assessed the negative priming effect and its sources by degrading target items on a subset of test displays. In the second experiment, we induced episodic retrieval on some test displays and observed the magnitude of the negative priming effect when we varied the accessibility of critical information from prime-display trials. In the third experiment, we sought to induce a broad-based retrieval strategy by manipulating the experiment-wide make-up of nonnegative priming trials. In all three experiments we used pronunciation, or naming, tasks in which participants read aloud stimulus words that flashed briefly on a computer screen. We chose naming rather than lexical decision as the response task because of the strong suggestion in the positive priming literature that lexical decision is influenced more by postlexical retrieval and checking processes than is naming (for a review, see Neely, 1991). Thus, negative priming tasks that use lexical decision (or other yes/no response tasks) may elicit episodic retrieval even in the absence of such manipulations as stimulus degradation (for a more detailed discussion, see May *et al.*, 1995).

The findings from the experiments reported here suggest that some experimental contexts do indeed induce the retrieval of prime-display information. Once episodic retrieval is induced, its disruptive effect on current responding depends critically on the probability that retrieval is successful (see Neill *et al.*, 1992). Finally, under other, nonretrieval circumstances, negative priming primarily reflects the inhibition accorded to a rejected distractor.

Experiment 1

The first two experiments, we compared the extent of negative priming when test display stimuli were (vs. were not) difficult to identify. Degraded exposures are known to enhance positive priming effects (e.g., West & Stanovich, 1982; Whittlesea & Jacoby, 1990), an outcome shown by Whittlesea and Jacoby to arise from the benefits of retrieving the previous context. Test-display targets that are degraded induce episodic retrieval of prime-display information, and thus the negative priming effect seen on such trials should primarily reflect episodic retrieval processes. We tested younger and older adults in our first experiment, in which we degraded some test displays and left others intact. For younger adults, we expected negative priming for both nondegraded and degraded trials: For the nondegraded trials negative priming would largely reflect inhibition, and for the degraded trials negative priming would largely reflect the interference caused by episodic retrieval. Furthermore, we expected larger negative priming effects on degraded trials than on nondegraded trials. For older adults, we did not expect negative priming on nondegraded trials because a sizable literature (e.g., Hasher et al., 1991; Kane et al., 1994; McDowd & Oseas-Kreger, 1991; Tipper, 1991) using such displays has failed to report such effects, leading to the conclusion (along with a growing body of data from other tasks; see, e.g., Hasher et al., in press; Zacks & Hasher, 1994) that older adults have deficient inhibitory mechanisms. Degrading the test-target stimuli would induce episodic retrieval in older adults (as it has in positive priming studies; see Madden, 1988, 1992), resulting in reliable negative priming under these conditions.

Finally, we conducted correlational analyses to assess whether negative priming resulted from the same or different *processes* in the *standard versus the degraded* conditions. If negative priming under nondegraded and degraded presentations reflects the action of different mechanisms, the two negative priming effects should be uncorrelated within each age group. If, however, negative priming is produced only by inhibition in both degraded and nondegraded display conditions, the following results would be expected: Younger adults should show reliable (and probably equivalent) negative priming in both conditions, older adults should show no negative priming in either condition, and for both age groups, degraded negative priming effects and nondegraded negative priming effects should be positively correlated.²

Method

Participants

Twenty-six younger adults (mean age = 19.0 years, range = 17-22) and 24 older adults (mean age = 67.9, range = 61-74) participated in the experiment. We recruited younger adults from undergraduate psychology classes at Duke University, and they participated in return for course credit. We solicited older adults from a registry maintained by the Duke University Center for the Study of Aging and Human Development; we paid them \$5 and reimbursed them for parking.

Materials

So that our results would be optimally applicable to the current negative priming literature, we chose for all of our experiments materials and procedures that would reflect the modal parameters of extant negative priming work (see Fox, 1995; May et al., 1995; Neill et al., 1995). Thus, the stimuli for the negative priming task were 10 unrelated, monosyllabic, five-letter nouns printed in lowercase type font (*frame, nurse, dress, brush, truck, grass, match, chair, stone, and clock*), with frequencies between 15 and 75 per million (Kucera & Francis, 1967). The stimulus set contained no rhyming words, no synonyms, and no words that formed a semantic unit when presented together (e.g., *box* and *car*).

The experiment consisted of 200 trials, each of which contained a prime display and a test display. All displays contained two stimulus words, one target and one distractor, each presented above or below a fixation point against a black background. For half of the participants, target words appeared in red and distractor words appeared in green; for the remaining participants, targets appeared in green and distractors appeared in red.

All trials contained visually intact stimuli on the prime display. One hundred, or half, of these trials were standard trials, containing visually intact test stimuli as well. For the remaining 100 trials, we manipulated the difficulty of test-target identification by means of the visual degradation of either the target or the distractor on

the test display. Degradation was achieved either by removing pixels from stimuli or by overlaying stimuli with visual noise. We used five different forms of degradation, two of which involved removing pixels from the stimulus words (in the shapes of & and W) and three of which involved overlaying the stimulus words with white symbols (in the shapes of /, =, and |). Per word, the percentage of pixels obscured by each form of degradation ranged from 23% to 50% (see Figure 2 for examples of each).

Fifty of the trials with degraded stimuli were degraded target trials, in which the target but never the distractor was degraded. For the remaining 50 trials, the distractor but not the target was degraded. We adopted this strategy to prevent participants from using degradation as an additional cue (beyond color) for test-target selection.

For each type of degradation (standard [no degradation], target, and distractor), 60% of all trials were control trials, in which no target or distractor words overlapped across prime and test displays. The remaining 40% of trials were negative priming trials, in which the distractor on the prime display served as the target on the test display. There were thus a total of six experimental conditions (see Figure 3): standard control (60 trials), standard negative priming (40 trials), degraded-target control (30 trials), degraded-target negative priming (20 trials), degraded-distractor control (30 trials), and degraded-distractor negative priming (20 trials). For every condition, each stimulus word served as a target and as a distractor an equal number of times in both prime and test displays. Within these constraints, combinations of word pairs were generated randomly. We interspersed the six different conditions pseudorandomly to make one list of trials, with the constraints that no condition was repeated on more than 2 consecutive trials and that no word that appeared in 1 trial's test display was repeated in the subsequent trial's prime display.



Figure 2. Examples of the five patterns of visual degradation used in Experiment 1.

Within the stimulus list, the top versus bottom positioning of targets and distractors was distributed equally and randomly across prime-test displays and across trial types; thus, on half of the trials the target remained in the same position (either above or below fixation) across the prime and the test displays, and on the other half the

target switched positions from the prime to the test display. In this way, stimulus location could not be used as a cue for selection.

In addition to the computerized word-naming task, participants also completed two written tasks: a health and demographic questionnaire and the Extended Range Vocabulary Test (ERVT; version 3) from the *Kit of Factor-Referenced Cognitive Tests* (Educational Testing Service, 1976).

	<u>Standard Negative Priming</u>	<u>Standard Control</u>
Prime:	frame nurse	frame match
Test:	nurse chair	nurse chair
	<u>Degraded Target Negative Priming</u>	<u>Degraded Target Control</u>
Prime:	frame nurse	frame match
Test:	nurse/ chair	nurse/ chair
	<u>Degraded Distractor Negative Priming</u>	<u>Degraded Distractor Control</u>
Prime:	frame nurse	frame match
Test:	nurse chair/	nurse chair/

Figure 3. Examples of the six trial types used in Experiment 1. Targets are printed in black; distractors are printed in white.

Design

The design of this experiment was a 2 (ages) x 6 (trial types) mixed factorial, with age varied between participants and trial type varied within participants.

Procedure

On the basis of a recent report that the time at which participants are tested may be an important variable to control in cognitive aging research (May, Hasher, & Stoltzfus, 1993), we tested all participants at the time of day previously found to be optimal for a significant proportion of that age group (younger adults between 1:00 p.m. and 5:00 p.m., older adults between 8:00 a.m. and 11:00 a.m.). We tested participants individually in a dimly backlit room. Ambient noise and light were constant across the day.

We presented the stimuli for the word-naming task on a Mitsubishi color monitor with an enhanced graphics adapter (EGA) card run by a program on an AT-compatible computer. The stimulus display consisted of two words, each 11 mm in height and 29 mm in width, presented one above the other and separated by an 8-mm space. Participants sat at their most comfortable distance 40-75 cm from the screen.

All participants first practiced using the microphone by naming visually presented digits. The instructions for the naming task then included a demonstration of a sample trial sequence followed by a practice block of 30

trials. This practice block included both standard and degraded trials. We included practice on degraded items to prevent extremely high error rates for these items in the experimental trials.

In both the practice and experimental lists, each trial began with a ready prompt (READY?) that remained onscreen until the participant pressed the computer space bar. (The use of this ready prompt allowed participants to pace themselves through the experiment and to take short breaks as needed.) After a 1,000-ms blank screen, a white fixation cross was displayed for 250 ms in the center of the screen (i.e., in the 8-inm space between the upcoming stimulus words). At the offset of the fixation cross, the prime stimuli appeared for 300 ms and were then immediately pattern masked by overlapping red and green symbols for 100 ms. The mask was followed by a fixed, 1,500-ms blank interval, in which the participant named the prime target aloud. After this fixed blank interval, the fixation cross for the test display appeared for 250 ms. The test stimuli were then exposed for 300 ms and pattern masked for 100 ms. Participants then named the test word aloud. At the end of each trial, participants received response time feedback on the screen for both prime and test displays. The experimenter sat behind the participant and recorded any naming errors. We did not provide participants with feedback about their accuracy, but we did explicitly instruct them to place an equal emphasis on fast and accurate responding throughout the experiment.

When participants completed the negative priming task, we questioned them about their awareness of the presence of negative priming trials. Five younger adults and 2 older adults reported being aware of this critical manipulation. Finally, participants completed the ERVT and the health questionnaire.

Table 1
Mean Response Times (in ms) and Error Rates for Younger and Older Adults by Trial Type in Experiment 1

Variable	Trial type					
	SNP	SC	DTNP	DTC	DDNP	DDC
Younger adults						
RT	506	499	564	542	491	499
ER	.05	.05	.07	.07	.06	.06
Older adults						
RT	546	547	680	652	528	530
ER	.03	.03	.16	.12	.01	.01

Note. RT = response time; ER = error rate; SNP = standard negative priming; SC = standard control; DTNP = degraded-target negative priming; DTC = degraded-target control; DDNP = degraded-distractor negative priming; DDC = degraded-distractor control.

Results Participant Comparisons

Because awareness of the negative priming manipulation has been shown to produce a pattern of response facilitation rather than impairment in the negative priming condition in some instances (e.g., Hasher et al., 1991; but see Neill & Valdes, 1992), we excluded from the analyses the data of the 7 participants who were aware of the negative priming condition. We assessed awareness by asking a set of questions, including a "catch trial" in which we asked the participant if he or she was aware of a trial type that actually did not appear in the experiment. We eliminated from the study only participants who reported awareness of the negative priming condition and also no awareness of this catch condition. Additionally, 3 older adults could not successfully identify degraded target words (their error rates on trials having degraded targets were 2.5 standard deviations above the group mean). We also eliminated their data from the analyses.

The remaining 21 younger adults had a mean age of 18.3 years (range = 17-22), and the 19 older adults had a mean age of 67.6 (range = 61-74). Older adults had significantly more years of education than younger adults ($M_s = 17.1$ and 12.4 , respectively), $F(1, 38) = 93.23$, $MSE = 222.633$, and reliably higher ERVT scores than younger adults ($M_s = 35.7$ and 27.0 , respectively; maximum score = 48), $F(1, 38) = 12.02$, $MSE = 716.447$.

Reaction Time

We eliminated all trials in which an error occurred on the prime or test display. Errors included trials on which participants named a nonpresented word, named the distractor, partially named the distractor, stuttered in naming the target, or made no naming response. Errors also included trials on which a voice--key failure occurred (because of equipment failure or insufficient response volume). We eliminated an average of 9.4% and 7.8% of trials for younger and older adults, respectively. Reaction times reflected means of medians for each age group and condition and are displayed in Table 1.

We conducted a 2 (ages) X 6 (trial types) mixed analysis of variance (ANOVA) on response times for test displays. For this and all subsequent analyses, the alpha level was set at .05. Younger adults were reliably faster than older adults, $F(1, 38) = 16.64$, $MSE = 14,439.62$. There was a reliable difference among trial types, $F(5, 190) = 158.54$, $MSE = 583.02$, and a reliable Age x Trial Type interaction, $F(5, 190) = 24.90$, $MSE = 583.02$. To address the source of this interaction, we conducted planned contrasts for those effects relevant to the theoretical framework, and these are reported below.

Impact of target and distractor degradation on control

trials. Because the induction of episodic retrieval relies on creating processing difficulties on test displays, our initial concern was to determine the impact of degrading a target on response times to test displays. We assessed the target degradation effect by comparing the reaction times on standard control trials with control trials having degraded targets. Degrading the target increased response time by 43 ms for younger adults, $F(1, 20) = 42.51$, $MSE = 915.35$, and by 104 ms for older adults, $F(1, 18) = 87.27$, $MSE = 2,376.26$; the slowdown shown by older adults was larger than that for younger adults, $F(1, 38) = 23.42$, $MSE = 1,607.36$. Thus, degrading the targets on test displays made the task more difficult for both younger and older participants, and the impact was substantially greater for older adults.

In a second set of analyses, we determined the impact of degrading a distractor on response times to test displays by comparing the response time on standard control trials with control trials having degraded distractors. Younger adults showed no effect of distractor degradation ($F < 1$), but older adults were facilitated (by 17 ms) when distractors were degraded, $F(1, 18) = 26.5$, $MSE = 213.65$. That older but not younger adults benefited from a reduction in distraction suggests that under standard visual conditions, older adults are differentially bothered by the presence of distractor items, a finding reported elsewhere (e.g., Madden, 1983; Plude, Hoyer, & Lazar, 1982; Scialfa & Kline, 1988; Scialfa, Kline, & Lyman, 1987).

Negative priming effects. We assessed negative priming effects for each age group by contrasting response times for each of the negative priming conditions (standard, degraded target, degraded distractor) with response times for their respective control conditions (standard, degraded target, degraded distractor). For the standard negative priming manipulation, in which all stimuli were visually intact, planned comparisons indicated a reliable negative priming effect for younger adults (of 7 ms), $F(1, 20) = 5.88$, $MSE = 158.33$, and an effect of the same order of magnitude that has been found before (e.g., Hasher et al., 1991; Stoltzfus et al., 1993). Older adults, however, demonstrated no difference (-1 ms) between negative priming and control conditions ($F < 1$). These results replicated previous findings of small, significant negative priming for younger but not for older adults with visually intact stimuli (Hasher et al., 1991; Kane et al., 1994; McDowd & Oseas-Kreger, 1991; Oseas-Kreger & McDowd, 1992; Stoltzfus et al., 1993; Tipper, 1991).

When we degraded the target on negative priming and control trials, younger adults demonstrated a reliable, 22-ms negative priming effect, $F(1, 20) = 13.71$, $MSE = 757.39$, and older adults also showed a reliable, 28-ms negative priming effect, $F(1, 18) = 9.25$, $MSE = 1,585.40$. The two effects did not differ ($F < 1$). Also, for both age groups the negative priming for the degraded-target condition was reliably larger than that seen for the standard negative priming condition: for younger adults, $F(1, 20) = 4.32$, $MSE = 1,179.26$; for older adults, $F(1, 18) = 8.99$, $MSE = 1,778.22$. In contrast to much of the extant literature, these results showed that reliable negative priming effects were elicited from older adults.

When we degraded the distractors on negative priming and control trials, neither younger nor older adults showed a reliable difference between negative priming and control trials ($F_s < 1.45$). The absence of negative priming here is similar to findings elsewhere (e.g., Allport et al., 1985; Lowe, 1979; Neill & Westbury, 1987; Tipper & Cranston, 1985) in which negative priming is eliminated or is even facilitatory when no distractor is present and hence when no selection is required.

Errors

We scored errors according to the criteria outlined above. Overall error rates are reported for each condition and age group and can be seen in Table 1.

We used the same analysis plan for error rates as we had used for response times, and the two dependent measures gave generally consistent results. There were reliable differences among trial types, $F(5, 190) = 23.68$, $MSE = 0.051$, and although there were no overall age differences in error rates ($F < 1$), there was a reliable Age X Trial Type interaction, $F(5, 190) = 13.46$, $MSE = 0.029$. We conducted planned comparisons to address the source of this interaction.

Impact of target and distractor degradation on control trials. When we degraded the target on test displays, both younger adults, $F(1, 20) = 5.06$, $MSE = 0.003$, and older adults, $F(1, 18) = 16.14$, $MSE = 0.01$, made more errors than when the target was not degraded. Similar to the response time data, this degradation effect was reliably greater for older adults than for younger adults, $F(1, 38) = 6.87$, $MSE = 0.042$.

The data for degraded-distractor trials relative to standard control trials were also in line with those seen for reaction time: Although younger adults showed no effect of distractor degradation (degraded-distractor control vs. standard control), $F(1, 20) = 1.59$, $MSE = 0.003$, older adults made significantly fewer errors in the degraded-distractor condition than in the standard condition, $F(1, 18) = 5.21$, $MSE = 0.074$. These data are consistent with the view that older adults are less able than younger adults to ignore intact distractors and hence their differential benefit when interfering distractors were degraded.

Negative priming effects. We compared error rates in each of the different negative priming conditions (standard, degraded target, degraded distractor) to their respective control condition (standard, degraded target, degraded distractor). There were no reliable differences (all $F_s < 1$), and therefore no error rate analyses suggested any evidence of speed—accuracy trade-offs.

Correlational Analysis

A correlation analysis³ indicated that standard negative priming effects were not significantly correlated with degraded-target negative priming effects for either younger or older adults ($r_s = -.379$ and $.112$, respectively, all $p_s > .10$; when the correlation for younger adults was rerun after an outlier [on the standard negative priming measure] was removed, $r = -.130$, $p = .59$).⁴

This pattern was also observed in a median split analysis for both groups; participants who showed less standard negative priming showed slightly more degraded-target negative priming ($M_s = 26$ ms and 32 ms for younger and older adults, respectively) than did participants who showed more standard negative priming ($M_s = 19$ ms and 24 ms for younger and older adults, respectively).

Discussion

Using the visually intact test displays common to previous research, we replicated earlier findings of significant negative priming for younger but not for older adults (e.g., Hasher et al., 1991; McDowd & Oseas-Kreger, 1991). Using degraded stimulus materials that made target identification more difficult (as evidenced by longer response times and increased errors for degraded-target conditions), we saw enhanced negative priming for younger adults (with a 22-ms effect vs. a 7-ms effect) and reliable negative priming for older adults (with a 28-ms effect vs. a —1-ms effect).

These findings are consistent with the idea that negative priming can have two sources. Under standard conditions, negative priming effects reflect identity inhibition, a mechanism impaired with age. By contrast, when target identification is impaired on test displays, prior context becomes useful and episodic retrieval is induced, increasing negative priming effects for younger adults and resulting in reliable negative priming for older adults. Note that because visual degradation occurred unpredictably on test displays, an inhibitory mechanism that acts on the prime-display distractor cannot account for these findings. Also consistent with the hypothesis that negative priming has two different sources was the absence of a correlational relationship between standard negative priming effects and degraded-target negative priming effects. In fact, the correlations for both age groups were slightly negative, a pattern also reflected by a median split analysis for both groups, in which participants who showed less standard negative priming showed slightly more degraded-target negative priming than did participants who showed more standard negative priming.

That younger and older adults show equivalent negative priming effects for degraded-target items is consistent with findings from the positive priming literature showing equivalent priming effects for younger and older adults (Madden, 1988, 1992). Nonetheless, these findings may be surprising because the present effects are thought to reflect retrieval processes, and older adults typically show retrieval deficits (for a review see Kausler, 1991; Light, 1996). However, the size of an individual's degraded-target negative priming effect critically depends not only on the success of any retrieval attempts but also on the number of trials on which a person retrieves. There is indeed a suggestion that older adults were induced to retrieve more often than were younger adults because older adults were differentially disrupted (in response time and error rate) by degraded versus nondegraded targets. Thus, although the younger adults may have been successful in retrieving prior information on a greater proportion of trials than were older adults, these two groups may have shown equivalent effects because the older adults retrieved on more trials than did the younger adults.

In summary, then, the pattern of negative priming effects produced by older and younger adults is dramatically altered when test-trial targets are made more difficult to identify. Whereas under standard conditions there is reliable negative priming only for younger adults, under degraded-target conditions there is reliable negative priming for older adults and enhanced negative priming for younger adults. Note also that neither age group showed a correlation between standard and degraded-target negative priming effects. Thus, these findings are consistent with the suggestion that negative priming can reflect episodic retrieval processes (for younger and older adults) under some select circumstances and inhibition (but for younger adults only) under others.

Experiment 2

Experiment 1 provided strong evidence that episodic re-trial can contribute to negative priming, at least under some circumstances. However, a limitation of Experiment 1 was that stimulus degradation not only produced large negative priming effects but also dramatically slowed participants' overall responding. It is possible, therefore, that the large negative priming effects found under degradation conditions in that experiment did not result from episodic retrieval but rather were artifacts of slowed responding. Of course, this hypothesis is not particularly compelling with respect to the data from older adults—who, by this logic, should demonstrate larger standard negative priming effects than should younger adults because older adults are slower. Nonetheless, because such arguments about slowed responding have been made with respect to degradation effects in the positive priming literature (e.g., Neely, 1991), we sought a manipulation that would induce episodic retrieval without affecting overall response times.

To this end, in Experiment 2 we varied the likelihood of inducing episodic retrieval on test displays by manipulating the test-display exposure duration, with either standard (300 ms) durations (as in Experiment 1; see also Kane et al., 1994) or brief (150 ms) durations. The brief-exposure durations, like the visual degradation in Experiment 1, limited the amount of stimulus information available on the test trial and thus should have forced participants to automatically retrieve antecedent information during test-target identification. Of particular relevance here is that pilot testing indicated that unlike visual degradation, short-exposure durations did not slow overall responding.

Experiment 2 also tested a critical prediction of the episodic retrieval view. Namely, if episodic retrieval is the source of negative priming under some circumstances, its efficacy will vary with the accessibility of information from previous displays (Neill & Valdes, 1992; Neill et al., 1992, 1995). If retrieval is induced and critical information (which here means the prior response tag) is highly accessible, then the negative priming effect will be large; however, if retrieval is induced but access to prior information is limited, negative priming effects will be small because without prior information, there is no competition between response codes.

To explore the prediction that when retrieval is induced the extent of negative priming will vary with the likelihood of retrieval success, we varied the stimulus-exposure duration of the prime display, using either standard (300 ms) displays or brief (150 ms) displays. Our view was that prime distractors are later more accessible if participants initially have more rather than less time to encode the prime display. We also sought to vary the likelihood of eliciting episodic retrieval on test displays by manipulating the test-display exposure duration, again either 300 ms or 150 ms. Because brief exposures trigger increased reliance on episodic retrieval and retrieval is more likely to be successful for the standard rather than for the brief prime-exposure condition, we expected to see the most negative priming when the prime display was long and the test display was short.

We tested only older adults because of the view they should produce negative priming as a result of episodic retrieval but not of inhibition, and therefore they should present a clearer picture of the parameters of episodic retrieval. One third of the participants saw standard prime and brief test displays (corresponding by analogy to the degradation manipulation in Experiment 1), one third saw both brief prime and test displays, and one third saw brief prime and standard test displays. Because episodic retrieval is induced when test-display information is limited, only the two groups with brief test displays were expected to retrieve prime-display information and thus show negative priming (from episodic retrieval). Furthermore, we predicted more negative priming for participants who retrieved information from standard prime displays than for participants who retrieved from brief prime displays because the former were more likely to have distractor response tags accessible than were the latter. On the basis of earlier work (Hasher et al., 1991; Kane et al., 1994; McDowd & Oseas-Kreger, 1991; Stoltzfus et al., 1993; Tipper, 1991), we did not expect participants who had a relatively long exposure to test-display information to engage episodic retrieval, and because older adults have impaired identity inhibition mechanisms, we did not expect negative priming when test displays were left intact.

Method

Participants

A new group of 90 older adults (mean age = 69.3 years, range = 60-76) participated in the experiment. We selected these participants from the same population described in Experiment 1, and we similarly compensated them for their participation.

Materials

We presented nine monosyllabic, three-letter stimulus words in capitalized letters (CAT, POT, JAR, TTE, CUP, FUN, GIN, BAG, and ROD), and each had a frequency of between 10 and 50 per million (Kucera & Francis, 1967).. These materials met constraints similar to those of Experiment 1.

The experiment consisted of 180 total trials: 36 control trials, 36 negative priming trials, and 108 filler trials. We mixed these conditions pseudorandomly to create two different stimulus lists; we randomly assigned each participant to one of these two lists. We included the filler trials to camouflage the negative priming condition. All other details about the construction of test materials were identical to those of Experiment 1.

Design

The experimental design was a 3 X 2 mixed factorial, with a between-subjects factor of stimulus duration (standard—brief, brief—brief, brief—standard, in which the first word represented the duration of the prime display and the second word represented the duration of the test display) and a within-subjects factor of trial type (control, negative priming).

Procedure

The procedure was identical to that of Experiment 1, with a few exceptions. The stimulus display consisted of two words, each 6 mm in height and 22 mm in width, presented one above the other and separated by a 2-min space. Participants sat at their most comfortable distance 35-75 cm from the screen.

The timing sequence for each trial differed from that used in Experiment 1 only in the exposure durations of prime- and test-display stimuli. Participants in the standard—brief group saw prime displays for 300 ms and test displays for 150 ms. Participants in the brief—brief condition saw both prime and test displays for 150 ms. Participants in the brief—standard condition saw prime displays for 150 ms and test displays for 300 ms. As in Experiment 1, prime- and test-display stimuli were masked for 100 ms.

Results Participant Comparisons

We replaced 5 participants in each stimulus-duration condition because they had excessively high error rates (>25%), and we eliminated from the analyses the data from 2 other participants who had outlying (excessively long) control reaction times (1 in the standard—brief condition and 1 in the brief—standard condition). All results reported here are for the remaining 88 participants (29 each in the standard—brief and brief—standard conditions and 30 in the brief—brief condition). These participants had a mean age of 68.2 (range = 61-76), a mean of 16.4 years of education, and a mean ERVT score of 36.7 (out of 48). There were no significant differences in age, education, or vocabulary scores among participants in the three stimulus-exposure conditions; furthermore, these values were similar to those for older adults in Experiment 1.

Reaction Time

The means of median test-trial response times (excluding error trials) for each trial type and age group are listed in Table 2. We scored errors according to the guidelines delineated in Experiment 1, and we eliminated from the reaction time analyses all trials in which participants made a prime- or test-display error (we deleted means of 6.0%, 6.5%, and 5.4% of trials per participant in the standard—brief, brief—brief, and brief—standard conditions, respectively).

Impact of stimulus-exposure duration. We conducted a 3 (stimulus exposure conditions) X 2 (trial types) mixed ANOVA on test-trial reaction times. Stimulus duration had no effect on overall response time ($F < 1$); thus, unlike the effect of the visual degradation manipulation used in Experiment 1, shortening test-trial exposure durations did not slow responses. Overall, responding was slower on negative priming trials than on control trials, $F(1, 85) = 11.21$, $MSE = 445.70$. There was also a reliable Stimulus Duration X Trial Type interaction, $F(2, 85) = 3.74$, $MSE = 445.70$.

Table 2
Mean Response Times (in ms) and Error Rates by Stimulus-Exposure Duration and Trial Type in Experiment 2

Stimulus-exposure duration	Trial type	
	Negative priming	Control
Standard—brief		
Response time	564	541
Error rate	.11	.12
Brief—brief		
Response time	565	557
Error rate	.11	.12
Brief—standard		
Response time	571	570
Error rate	.08	.05

Negative priming effects. Planned contrasts indicated that negative priming (i.e., the difference between control and negative priming response times) was reliable for the standard—brief display condition (with a 23-ms effect), $F(1, 28) = 13.61$, $MSE = 533.53$, and marginally significant in the brief—brief condition (with an 8-ms effect), $F(1, 29) = 3.14$, $MSE = 324.38$, $p = .09$. The 1-ms negative priming effect was not significant for the

brief—standard group ($F < 1$), replicating the now-common finding that older participants fail to show negative priming when test-trial stimuli are easily identified (e.g., Hasher et al., 1991) and confirming the finding from Experiment 1 that a critical condition for producing negative priming with older adults is difficult target identification on test trials.

Furthermore, consistent with our prediction that highly accessible prime displays would increase retrieval success (and therefore the size of negative priming effects), the negative priming effect for the standard—brief group (23 ms) was marginally larger than that for the brief—brief group (8 ms), $F(1, 57) = 3.45$, $MSE = 427.12$, $p = .07$.

These results point to two main conclusions: (a) Degraded, or very brief, test displays are sufficient to induce episodic retrieval in older adults and (b) when the test display is brief, intact prime displays yield larger negative priming effects than do very brief prime displays. Thus, to produce negative priming in older adults, participants must be induced to retrieve, and when they do, the amount of negative priming varies with the accessibility of the to-be-retrieved information. Under very brief prime-exposure durations, there may be a decreased probability that competing information about the prime distractor's characteristics will be successfully retrieved should the next test display be a negative priming one presented under conditions that induce such retrieval.

Errors

Again, the analysis plan for errors mirrored that for response times (mean error rates for each condition are displayed in Table 2).

Impact of stimulus duration. Stimulus duration had a significant effect on test display error rate, $F(2, 85) = 6.19$, $MSE = 0.008$. Specifically, participants who saw brief test displays had higher error rates than did participants who saw standard test displays ($M_s = .11$, $.11$, and $.07$ for standard—brief, brief—brief, and brief—standard groups, respectively). These data suggest that although participants who saw shortened test displays were not reliably affected in response time, they did make more errors with briefly exposed stimuli. Thus, as in Experiment 1, the degradation method used here did create some degree of processing difficulty for participants.

Negative priming effects. Overall, participants had equivalent error rates on control trials ($.09$) and on negative priming trials ($.10$; $P < 1$), an effect qualified by a reliable Stimulus Duration X Trial Type interaction, $F(2, 85)$ $MSE = 0.002$.

Planned comparisons indicated no differences between control and negative priming trials for the standard—brief or the brief—brief group ($F_s < 1$). It is important to note that these error rate results indicate that the negative priming effects evidenced by these groups in response times were not compromised by speed—accuracy trade-offs. However, a significant difference between control and negative priming conditions was evident in the brief—standard group ($M_s = .05$ and $.08$, respectively), $F(1, 28) = 17.96$, $MSE = 0.001$, a condition that had shown no effect in response times.

The finding here of negative priming in error rate (of $.03$) for participants in the short—long condition (a condition that should not have elicited episodic retrieval) was unexpected and is inconsistent with our framework. Because there were only 36 trials per condition, however, this represents a mean difference of only one item per participant. Note that these participants were on average far from showing negative priming in response time; hence we are tempted to consider this error effect to be inconsequential. However, in light of the rather small response time effects that are typical in negative priming studies (i.e., in the 10-ms range), we do not dismiss this error rate result but rather allow it as one piece of evidence inconsistent with our view.

Discussion

In Experiment 2, our two goals were to confirm the role that episodic retrieval can play in negative priming and to do so in such a way that overall response times were not affected. In reference to the latter goal, our manipulation of the stimulus-exposure duration was successful in addressing the potential limitation of Experiment 1 by producing episodic retrieval effects without slowing overall response rates.

The findings of Experiment 1 led us to expect that negative priming effects would be obtained when test display stimuli were degraded (in Experiment 2 by brief-exposure duration) because under these circumstances episodic re-retrieval processes are engaged. Furthermore, we expected that when episodic retrieval was induced, negative priming effects would be larger when prime displays were intact (as opposed to shortened) as a result of the relative accessibility of their response code information. Both predictions were supported, as discussed below.

As in Experiment 1, the older adults tested here demonstrated negative priming (in response times) only when test-trial stimulus information was limited. No such negative priming was seen for the 300-ms test-display condition. In addition, our predicted finding of greater negative priming for the standard—brief (23 ms) than for the brief—brief (8 ms) exposure duration groups provides evidence that the likelihood of showing large negative priming effects is associated with the accessibility of information from the prime display.

Considered together, Experiments 1 and 2 generally demonstrate that under standard, visually intact display conditions, younger adults show negative priming and older adults do not. However, when test trials are difficult to process, either because of visual degradation of stimuli (Experiment 1) or shortened stimulus-exposure durations (Experiment 2), older adults show significant negative priming, and (in Experiment 1) younger adults' effects increase in magnitude. Finally, when test-display information is limited, the magnitude of the negative priming shown by older adults depends on the probability of successfully retrieving information from the prime display: The better the encoding afforded by the prime display, the more likely it is that codes, including those specifying response demands, are retrieved to produce negative priming (Experiment 2).

These findings (along with the absence of either a correlation or a median split difference between standard and degraded-target negative priming effects in Experiment 1) are best explained by a dual mechanism account of negative priming, whereby under standard conditions, only younger adults produce the effect by means of inhibitory processing of distractors. When test-display stimuli are difficult to process, surrounding context (information from previous displays) is searched, resulting in negative priming caused by conflicting response codes from the current target's current tag to respond and its previous tag as a distractor.

In fact, the combined results of Experiments 1 and 2 cannot be accounted for by a forward-acting inhibitory mechanism. If degraded-target negative priming effects were merely a by-product of slowed responding (which also slowed the accrual of activation and so allowed for the detection of negative priming effects), then the large degraded-target negative priming effects for older adults should not have been replicated in Experiment 2, in which the test-display degradation manipulation did not increase response times. Furthermore, if overall response speed alone were the critical variable in producing negative priming, then older adults should demonstrate larger negative priming effects than should younger adults under both degraded and standard conditions because older adults are consistently slower than young adults in these (and other) circumstances. Clearly, neither of these predictions is supported by the data.

Experiment 3

Experiments 1 and 2 demonstrated that episodic retrieval is induced when test stimuli are difficult to process and that when induced, episodic retrieval is more successful if prime-display information is highly accessible. Because the source of negative priming effects is altered when episodic retrieval is operating, a critical question concerns what other conditions or contexts might induce episodic retrieval.

On the basis of the logic of the episodic retrieval view, it follows that episodic retrieval should be induced in situations in which the retrieved prime information aids current target identification (Logan, 1988; Neill &

Valdes, 1992; Neill et al., 1992). In Experiments 1 and 2, episodic retrieval was induced because of difficulty in identifying the target. Retrieval might also be induced in situations in which the prime-display target repeats as the subsequent test-display target; in such cases, retrieval would speed response time, as both the name and the response tags match across the two displays. It is possible that the inclusion of a large proportion of repeated-target trials in a negative priming experiment may invoke episodic retrieval across all of the different trial types in the experiment.

If, as has been demonstrated in Experiment 1; negative priming from episodic retrieval produces larger effect sizes than does negative priming produced by inhibition, then a primary consequence of a list that includes trials with repeated targets should be larger negative priming effects, than is seen in designs that do not include repeated-target trials. In fact, there is some indirect evidence of this in the negative priming literature (for examples of studies that include repeated-target trials, see Allport et al., 1985; Lowe, 1979; Neumann & DeSchepper, 1991, Experiment 1; Tipper & Driver, 1988; but see Neumann & DeSchepper, Experiment 2, for an exception). Our primary goal in Experiment 3 was thus to elicit episodic retrieval (and negative priming) in older adults without degrading critical stimuli but by incorporating a large number of repeated-target trials into the experimental sequence.

A secondary goal was to test a hypothesis of Kane et al. (1994) regarding yet another trial type, the target-to-distractor trial type, in which a prime target repeats as the test distractor (see Hinton, 1976; Neill, 1978). Performance on this trial type may serve as a marker for the source (inhibition vs. episodic retrieval) of negative priming effects because different outcomes should be obtained on target-to-distractor trials depending on whether inhibition or episodic retrieval is generally operating. When episodic retrieval is engaged, stimulus repetition across two successive displays should result in the retrieval of the prior display's information. When successful, such retrievals should facilitate responding to repeated-target trials and should slow responding to target-to-distractor (and negative priming) trials. This slowing occurs relative to control trials because information from the prime display conflicts with information on the test display. The result of this response code conflict, then, is slowed responding on target-to-distractor trials. Thus, if the inclusion of repeated-target trials elicits an experiment-wide episodic retrieval process, a slowdown on target-to-distractor trials as well as on negative priming trials would be expected.

By contrast, findings from the literature show that in contexts that are unlikely to induce episodic retrieval, the target-to-distractor condition is not disrupted relative to the control condition. In fact, facilitation is typically observed on target-to-distractor trials (e.g., Hinton, 1976; Neill, 1977; see Kane et al., 1994, for such findings with both younger and older adults). Although a definitive explanation of this facilitation effect has yet to be offered, Kane et al. suggested that in experimental contexts that do not include repeated targets, target-to-distractor trials are facilitated because across the experiment, participants learn that a prime-display target never appears as a target on a subsequent test display; thus a prime target is never a candidate for the subsequent display's response. In a sense, then, prior targets are consistently mapped onto the role of distractors (e.g., Schneider & Shiffrin, 1977); as a result, when these targets become distractors they are relatively easy to ignore. As evidenced by the substantial literature on visual search, both older and younger adults are quite good at ignoring stimuli that predictably occur in a distractor role (e.g., Carlson et al., 1995; Fisk, McGee, & Giambra, 1988; Fisk & Rogers, 1991; Plude & Hoyer, 1981; Plude et al., 1982).

Thus, we modified the task used by Kane et al. (1994), which included negative priming and target-to-distractor conditions as well as standard, nondegraded stimulus-exposure durations of 300 ms. Kane et al. found no negative priming for older adults (actually, they found a nonsignificant 3-ms facilitation effect), coupled with substantial (10 ms) target-to-distractor facilitation. In this experiment, we tested older participants and changed one aspect of the task—adding a repeated target condition—designed to elicit episodic retrieval.

Method

Participants

We solicited a new group of 20 older participants (mean age = 69.4 years, range 61-75; mean education = 15.6 years; mean ERVT score = 36.1 out of 48) from the same participant pool as in Experiments 1 and 2, and these participants were similarly compensated. Again, the advantage of using older participants is that in conditions that do not induce episodic retrieval, they do not show a negative priming effect.

Material, Design, and Procedure

Materials were identical in every aspect to those used in Experiment 2 (and to those used by Kane et al., 1994) except that we included both repeated-target and target-to-distractor trials.

The experimental design included the within-subjects variable of trial type. The four critical trial types were as follows: (a) control, in which all of the stimuli on prime and test displays were unrelated (20% of trials); (b) negative priming, in which the distractor on the prime display repeated as the target on the test display (20% of trials); (c) target-to-distractor, in which the target on the prime display repeated as the distractor on the test display (20% of trials); and (d) repeated target, in which the target on the prime display repeated as the target on the test display (40% of trials).

Our procedure was identical to that of Kane et al. (1994) and to those of Experiments 1 and 2 (except that all stimuli in Experiment 3 were intact and all stimulus words were presented for 300 ms).

Results

Reaction Time

Means of median test-trial response times for each trial type (after excluding errors) are presented in Table 3. A one-way repeated measures ANOVA indicated a reliable effect of trial type, $F(3, 57) = 7.93$, $MSE = 125.10$. Of primary theoretical interest, subsequent planned contrasts indicated a reliable 8-ms slowdown for negative priming trials relative to control trials, $F(1, 19) = 11.503$, $MSE = 116.91$. Older adults thus produced reliable negative priming within this experimental context. In addition, a reliable 7-ms slowdown was evidenced for target-to-distractor trials versus control trials, $F(1, 19) = 13.33$, $MSE = 68.88$. Finally, a marginally significant, 7-ms facilitation effect was indicated for repeated-target trials versus control trials, $F(1, 19) = 3.39$, $MSE = 301.85$, $p = .08$.

Errors

Mean error rates for each condition are presented in Table 3. In this experiment, a marginally significant effect of trial type was indicated by a one-way repeated measures ANOVA, $F(3, 57) = 2.66$, $MSE = 0.002$, $p = .06$. However, planned comparisons indicated no differences between the pairwise comparisons of interest (i.e., control trials with each of the other trial types; all $ps > .10$). Thus, although a speed-accuracy trade-off between repeated-target and control trials appeared in the mean data (between repeated target and control), it was not statistically significant. Given the small sample size, however, we would not draw strong conclusions about a speed-accuracy trade-off in the repeated-target condition. There is, however, no evidence that the other two response time effects resulted from a speed-accuracy trade-off.

Discussion

By modifying the context of Kane et al.'s (1994) procedure into one that should elicit episodic retrieval, we obtained dramatically different findings in Experiment 3. Recall that in Kane et al.'s study, older adults showed no negative priming (a 3-ms facilitation effect) and substantial target-to-distractor facilitation (10 ms). In Experiment 3 of our study, older adults demonstrated reliable negative priming (8 ms), a significant target-to-distractor impairment (7 ms), and repeated-target benefit (7 ms).

Table 3
Mean Response Times (in ms) and Error Rates by Trial Type in Experiment 3

Variable	Trial type			
	Control	Negative priming	Target to distractor	Repeated target
Response time	532	540	539	525
Error rate	.04	.04	.04	.07

The critical—and only—difference between Kane et al.'s (1994) study and this experiment was our inclusion of a large proportion of repeated-target trials, a manipulation intended to induce episodic retrieval across the entire experiment. Indeed, the data suggest that we were quite successful in that responding was impaired whenever response codes for a given item mismatched across prime and test displays (i.e., on both negative priming and target-to-distractor trials), and responding was slightly facilitated when response codes for a given item matched across prime and test displays (i.e., on repeated-target trials). These findings thus indicate that episodic retrieval can be induced (or not induced) by the inclusion (or exclusion) of list conditions that encourage episodic retrieval.

Note, however, that the negative priming effect size shown by older adults in Experiment 3 (8 ms) was considerably smaller than that seen with degraded targets in Experiment 1 (28 ms) and with the long–short stimulus duration in Experiment 2 (23 ms). This discrepancy in effect sizes across our three experiments may reflect that the procedures differed in how effectively they induced episodic retrieval across participants. As measured by the number of participants affected by the retrieval-inducing manipulation, Experiments 1 and 2 were quite successful. In Experiment 1, degrading test targets increased the response times and error rates (relative to standard trial times and error rates) for more than 95% of the younger and older participants, and approximately 76% of younger and 95% of older participants demonstrated degraded-target negative priming effects larger than 5 ms. Similarly, in Experiment 2, more than 80% of the participants in the long–short stimulus-duration condition had higher error rates than the mean error rate of those in the short–long stimulus-duration condition; in addition, over 75% of the participants in the long–short stimulus-duration condition showed negative priming effects greater than 5 ms.

In contrast, the repeated-target manipulation of Experiment 3, which we hypothesized would induce an experiment-wide episodic retrieval process, had a less widespread effect. Only 50% of these participants showed more than 5 ms of facilitation on repeated-target trials. With so few participants deriving a benefit from the repeated-target condition, one would not expect as strong an inducement of negative priming (or as large an effect size) in this experiment as in Experiments 1 and 2. Indeed, only 65% of the older participants in Experiment 3 showed a negative priming effect of larger than 5 ms.

Because only half of the participants in Experiment 3 appeared to have been influenced by the presence of repeated-target trials, we sought an additional appraisal of our predictions: Older adults who showed negative priming in this procedure would have done so by means of episodic retrieval and so should also have demonstrated substantial repeated-target facilitation. Our informal method was thus to divide our group of participants into quartiles on the basis of their repeated-target scores and to compare the negative priming effects for the highest and the lowest quartiles. We also divided our participant groups into quartiles on the basis of their negative priming scores and compared the repeated-target effects for the highest and the lowest quartiles. The data from both comparisons seemed to be consistent with our predictions. Participants who showed the most repeated-target benefit ($M = -30$ ms) showed a larger negative priming effect ($M = 14$ ms) than did participants who showed a repeated-target slowdown (for the repeated-target effect, $M = 14$ ms; for the negative priming effect, $M = 5$ ms). Similarly, participants who showed the most negative priming ($M = 21$ ms)

showed a sizable repeated-target facilitation effect ($M = -16$ ms), whereas participants who showed the least negative priming ($M = -6$ ms) actually showed a slight slowdown on repeated-target trials (of 4 ms).

The finding of a reliable negative priming effect for older adults in Experiment 3 is especially important in that it demonstrates that episodic retrieval may operate in experimental contexts that are quite common to the negative priming literature, and when it does, the pattern of data is quite different from that which results solely from inhibition. Consider a recent demonstration of negative priming in older adults (Sullivan & Faust, 1993; see also Sullivan et al., 1995): The procedure used was unique among studies on aging in its inclusion of repeated-target and semantically related target-trial types. On a substantial percentage of trials in the procedure used by Sullivan and colleagues (40%, as in our Experiment 3), a prime target repeated as a test target or a semantic associate of the prime target repeated as a test target. These are precisely the sorts of conditions under which episodic retrieval is likely to be induced, and as such it seems unlikely that the older adults in the studies by Sullivan and colleagues were displaying inhibition-mediated negative priming. Rather, there as here, negative priming was likely the result of inducements to retrieve information from prior displays, a process that when successful, results in competition between response codes on negative priming type trials, thus slowing responding.

General Discussion

The present experiments demonstrate that for both younger and older adults, the extent of negative priming can vary from none at all to a substantial amount. The experimental determinants of the size of the effect (if any) are how easy the stimuli are to detect or decode on a test display (Experiments 1 & 2) and the nature of the experiment-wide context (Experiment 3), in particular, the mix of carryover conditions included with negative priming trials. These data join a substantial literature that even includes demonstrations of facilitatory negative priming effects (e.g., Lowe, 1979) to show that negative priming effects are not fixed either within or across ages.

The present data support the view that like positive priming, negative priming is determined by (at least) two separate mechanisms: in the present instance, inhibition and episodic retrieval. At least this is the case for younger adults. For older adults, by contrast, negative priming appears to be determined by whether or not episodic retrieval is induced (Experiments 1-3). If it is not, no negative priming is seen (Experiments 1 & 2; see also Hasher et al., 1991; Kane et al., 1994; Kwong See et al., 1994; McDowd & Oseas-Kreger, 1991; Stoltzfus et al., 1993; Tipper, 1991; but see the error rate effect for the brief—standard group in Experiment 2), consistent with the view that inhibitory efficiency diminishes with age across the adult life span (Hasher & Zacks, 1988; Zacks & Hasher, 1994).

Can an explanation of negative priming based purely on inhibition account for the present findings of inflated effects under degraded-stimulus (Experiments 1 & 2) and repeated-target conditions (Experiment 3)? Because inhibition is a forward-acting process, the inclusion of degraded test displays in Experiments 1 and 2 would have had to provoke an anticipatory increase in prime-display distractor inhibition. That is, participants could have increased their inhibition of prime distractors in anticipation of degraded test displays. Such an explanation might be plausible for the findings of Experiment 2, in which participants who showed negative priming always saw degraded test displays. However, an anticipatory explanation cannot account for the enhanced negative priming in Experiment 1, in which both degraded and intact test displays were randomly presented within the same list. Any anticipatory change in prime-display processing would have affected both standard and degraded test trials and would have produced similar results in these two conditions. This was not the case. Finally, with respect to Experiment 3, the extant negative priming literature does not suggest at either a theoretical or a post hoc explanatory level how the inclusion of repeated-target trials in an experimental context would affect the inhibition of distractors. Thus, inhibition does not accommodate all the data in this series of studies, but neither can episodic retrieval.

Neill and colleagues (Neill & Valdes, 1992; Neill et al., 1992, 1995) have suggested that inhibition may play no role in negative priming; the effect may entirely reflect code conflict that results from successful episodic

retrieval. Those holding such a view would argue that the contextual manipulations described in our experiments merely had different effects on the probability of inducing retrieval. Perhaps participants retrieve prime information with some probability on standard trials, but on degraded-target trials (or in designs with repeated targets), that probability is greatly *increased*, and on degraded-distractor trials, that probability is dramatically decreased. Such a view would predict results similar to those reported here--larger negative priming effects for degraded-target trials than for standard trials and smaller negative priming effects for degraded-distractor trials than for standard trials.

Several of our findings, however, suggest that episodic retrieval cannot account for all of negative priming. First, if standard and degraded negative priming effects were produced by the same process, these effects should be positively correlated, and they were not in Experiment 1 (by either a correlational analysis or a median split analysis). Furthermore, if under standard conditions older adults are less likely than younger adults to engage in episodic retrieval (as evidenced by their lack of standard negative priming effects), then under degraded-target conditions they should also be less likely than younger adults to retrieve prime information and thus should show smaller negative priming effects than younger adults. We did not obtain these results in Experiment 1.

Other evidence against an explanation of negative priming based purely on episodic retrieval comes from comparing negative priming and target-to-distractor effects within an experiment. Episodic retrieval should produce outcomes similar to those two effects (i.e., a slowdown caused by mismatches between retrieved response tags); when episodic retrieval is present, a target-to-distractor slowdown should also be seen. This, however, is not the typical pattern of findings; target-to-distractor effects are most often facilitatory (e.g., Hinton, 1976; Neill, 1977), even in experiments that concurrently demonstrate reliable negative priming effects (e.g., Kane et al., 1994). Thus, if episodic retrieval is not encouraged across the experiment, then negative priming and target-to-distractor effects do not show a positive relationship; if episodic retrieval is encouraged across the experiment (e.g., by including many repeated-target trials), then negative priming and target-to-distractor effects produce similar response impairments.

Finally, other limits of episodic retrieval theory in accounting for the entire negative priming literature are detailed by May et al. (1995); only a critical few are briefly summarized here:

1. In a within-subjects design, negative priming effects should continue to decrease over increasing RSIs (as stimulus episodes become less and less temporally discriminable from each other); however, whereas negative priming effects decline at RSIs of approximately 500 ms, there is no reliable decline thereafter (with significant negative priming effects at least through 8,000 ms; see Neill & Valdes, 1992).
2. If an intervening stimulus appears between prime and test displays, the prime display should become less discriminable from the intervening stimulus and should therefore be very difficult to retrieve, especially if that intervening stimulus is similar to the prime; however, negative priming effects persist across one, to several, intervening stimuli (e.g., DeSchepper & Treisman, 1991; Tipper et al., 1991).

All this is not to suggest, of course, that episodic retrieval plays no role in negative priming. Although episodic retrieval may not be an automatic process that operates in all situations, our data indicate that it can produce negative priming for distractor identities, at least in some contexts. Recent data from spatial localization tasks (Milliken, Tipper, & Weaver, 1994; Park & Kanwisher, 1994; Tipper, Weaver, & Houghton, 1994; Tipper, Weaver, & Milliken, 1995) have suggested a similar conclusion regarding negative priming for distractor locations. Namely, in an experimentwide context in which participants are precued to the upcoming target stimulus dimension (e.g., the color or the identity of the target), negative priming may be produced by the retrieval of stimulus feature information that mismatches the features currently associated with the target location. Tipper and colleagues have not yet made predictions about what other kinds of experimental contexts might elicit feature retrieval in negative priming involving localization tasks; however, all of the findings taken together allow the conclusion that in both identification tasks and localization tasks, negative priming may be produced by inhibition in some contexts and episodic retrieval in others.

The conclusion that negative priming is dually determined has several important implications. Not only has negative priming been seen as providing evidence for the existence of attentional inhibitory mechanisms, but its utility as an inhibitory index has also fueled a rapidly growing literature concerning populations thought to suffer from inhibitory deficits, such as older adults (Hasher et al., 1991), children (Tipper et al., 1989), patients with schizophrenia (e.g., Beech et al., 1989), patients with obsessive-compulsive disorder (e.g., Enright & Beech, 1990), and individuals who are depressed (e.g., Linville, 1996). We suggest that investigators who wish to use negative priming as an index of inhibitory processing take care to avoid experimental designs that might induce episodic retrieval, such as using visually degraded stimuli (either by the addition of visual noise or by the use of overlapping stimuli) or extremely brief test displays, including repeated-target trials, or providing precues (see May et al., 1995, for speculations on other procedures, such as yes-no decision tasks, that may also induce episodic retrieval). Furthermore, researchers who study individual differences in inhibitory efficiency must be concerned that a finding of significant negative priming does not always reflect the action of an intact inhibitory mechanism. As discussed earlier, for example, the failures to obtain age differences in negative priming involving identification tasks that have been reported by Sullivan and colleagues (Sullivan & Faust, 1993; Sullivan et al., 1995) were not likely to have been driven by preserved inhibitory functioning in older adults but rather by episodic retrieval processes that were induced by the inclusion of a large proportion of repeated-target trials in their experiments.¹

A productive research strategy, particularly for those interested in individual and group differences in inhibition, would be to use a design such as that of Experiment 1, which permits the contributions of inhibition and episodic retrieval to be assessed within the same task, and/or to include target-to-distractor trials in the design, which may act as an effective marker of whether episodic retrieval is operating (with facilitation effects when episodic retrieval is absent and slowdown effects when episodic retrieval is present). The clear conclusion from the present studies is that negative priming is multiply determined by inhibition and episodic retrieval.

Notes:

1 Recently, several studies on negative priming involving identification have shown equivalent negative priming for older and younger adults. Details of their procedures, however, suggest, as we discuss later, that factors other than inhibition were operating in each (Kramer, Humphrey, Larish, Logan, & Strayer, 1994; Sullivan & Faust, 1993; Sullivan et al., 1995).

2 Of course the correlation between negative priming effects should also be positive if both are produced by episodic retrieval as well.

3 Although classic arguments have been made against the validity of correlating difference scores (e.g., Cronbach & Furby, 1970), more recent views have supported this strategy (e.g., Rogosa, Brandt, & Zimowski, 1982; Willett, 1989). In particular, difference scores were criticized in the developmental literature, where it was often difficult to determine whether change produced by an experimental manipulation was beyond what would be expected by the natural course of the process in question. Thus, a difference score (between pre- and postmanipulation) was inherently problematic, true change was impossible to determine given a potentially changing baseline. However, in the present instance, our difference scores represented true change. That is, our baseline condition (control response times) would have looked no different whether or not we had included the experimental condition (negative priming trials). In fact, several of our published studies (Hasher et al., 1991; Stoltzfus et al., 1993) presented control and negative priming trials in separate blocks and produced standard negative priming effects. Furthermore, response times to this control condition remained stable across the experiment. Differences between control and negative priming response times thus cannot be attributed to a naturally occurring (or experimentally induced) change in baseline. Our difference scores here are therefore similar to any other slope values that researchers correlate, and the statisticians cited previously would, we believe, support our use of this statistic.

4 We also conducted rank-order correlations within age groups. Neither group showed reliable correlations between participants' relative rank in standard negative priming scores and degraded-target negative priming scores (for younger adults, $r = -.237$; for older adults, $r = -.010$; $ps > .30$).

5 Kramer, Humphrey, Larish, Logan, and Strayer (1994) also found that younger and older adults demonstrated equivalent negative priming effects in a letter-naming task, suggesting intact inhibitory capabilities for older adults. Their particular methodology, however, allows for an alternative interpretation of their findings. Specifically, in their experiment, the target item in every display appeared in one of four possible locations, with distractor items appearing in the remaining three locations. Given that all locations were occupied by either a target or a distractor on every display, the target item on the test display necessarily appeared in the same location as either a prime distractor or the prime target. Thus, the slowing evidenced on test trials may have resulted not from identity inhibition but rather from a combination of location inhibition (when the test target appeared in the same location as a prime distractor) and inhibition of return (when the test target appeared in the same location as the prime target; see Posner & Cohen, 1984).

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