Inhibitory Attentional Mechanisms and Aging

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Abstract:
Two experiments sought to elicit distractor suppression in older adults. Experiment 1 used a procedure that increased suppression in younger adults, thus creating a more sensitive measure of suppression in older adults. To compensate for older adults' slowed processing, Experiment 2 used a longer stimulus exposure duration. Neither experiment produced suppression in older adults; both experiments, however, included trial types that elicited parallel facilitatory effects for both age groups. Older adults thus seemed to process distractors but failed to engage inhibitory mechanisms in their rejection of distracting stimuli. Finally, both experiments tested the relationships among suppression, interference, and everyday cognitive failure. Neither experiment suggested relationships between reaction time effects and self-reported cognitive lapses. Results are discussed within L. Hasher and R. T. Zacks's (1988) attentional framework.

Article:
The study of selective attention has largely focused on the ways in which relevant target information becomes highlighted against irrelevant distractor or background information. The fate of attended-to but unselected stimuli, beyond the assumption of a passive decay process, has not been a traditional focus of theoretical or empirical work (e.g., Broadbent, 1982; La-Berge, 1983; Treisman, 1986). There is, however, a growing literature suggesting that items selected against are not simply passively ignored but rather are actively suppressed (Tipper, 1985; Tipper & Cranston, 1985) or "disattended" (Neill, 1977). Such findings are consistent with theoretical views arguing that selective attention depends on both excitatory and inhibitory processes. According to such views, relevant stimuli are targeted for processing, and unselected stimuli are actively disengaged from potential response systems (e.g., Allport, Tipper, & Chmiel, 1985; Navon, 1989a, 1989b; O. Neumann, 1987).

Consistent with Hasher and Zacks's (1988) recent proposal that inhibition of unselected stimuli plays a central role in a wide variety of cognitive tasks, including memory, language comprehension, and speech production, we suggest that it is important to examine directly the fate of unselected or to-be-ignored stimuli. To be more specific, Hasher and Zacks proposed that inhibitory mechanisms that ordinarily serve to hinder or prevent access to working memory of selected-against stimuli may be deficient in older adults and so may be implicated in patterns of impaired performance they demonstrate across a broad range of behaviors, including comprehending, remembering, and discussing events. For example, in comparison with younger adults in tests of language comprehension, older adults have more difficulty ignoring distracting text while they are reading (Connelly, Hasher, & Zacks, 1991; Shaw, Rypma, & Toffle, 1992). They show activation to a broader range of potential candidate words that complete a sentence (Stoltzfus, 1992) and to a broader range of interpretations that are consistent with a passage (Hamm & Hasher, 1992). Older adults also show more sustained activation of considered but rejected sentence completions (Hartman & Hasher, 1991) and passage interpretations (Hamm & Hasher, 1992) than do younger adults. Older adults are more vulnerable to retrieval problems created by broadspread activation (e.g., the fan effect; Gerard, Zacks, Hasher, & Radvansky, 1991) as well. These and other age-related differences may result from older adults' inability to effectively inhibit the processing of marginally relevant, irrelevant, and/or distracting stimuli and thoughts.

Empirically, inhibitory mechanisms of selective attention may be inferred from experimental tasks that require subjects to respond to a target item presented simultaneously with a similar distractor item. On critical pairs of trials, the distractor item from the previous trial becomes the target item. On such "distractor suppression" trials, young adults' responding to the target is slowed relative to their responding when there is no relationship between distractors and targets occurring across successive pairs of trials (e.g., Dalrymple-Alford & Budayr, 1966; Lowe, 1979; Tipper, 1985). This response impairment, called *suppression* or *negative priming,* is believed to result from inhibition directed toward the previously selected-against distractor item.[1]

Age differences in attentional inhibition have only recently been explored in the context of such suppression tasks. Results are consistent with the predictions of the Hasher and Zacks (1988) framework: Although young adults show a suppression effect on critical trials, older adults do not (Hasher, Stoltzfus, Zacks, & Rypma, 1991; McDowd & Oseas-Kreger, 1991; Stoltzfus, Hasher, Zacks, Ulivi, & Goldstein, 1993; Tipper, 1991). Because these findings suggest a mechanism for older adults' patterns of cognitive failures, they are extremely important theoretically, and their limitations need to be examined.

One issue of considerable concern is the size of the suppression effect typically shown by younger adults in many of these studies. Although they are both statistically reliable and are shown by a substantial majority of individuals, suppression effects are often very small. For example, in our work (Hasher et al., 1991; Stoltzfus et al., 1993), the suppression effect hovers just under 10 ms for younger adults. This leaves little room to detect what might well be a weaker suppression effect in older adults. Thus, in the first experiment, we sought procedures that would increase the size of the suppression effect in younger adults, in the interest of creating a more sensitive measure of suppression to use with older adults. As will be seen, we were successful in increasing the magnitude of the suppression effect shown by younger adults.

A second limitation to drawing strong conclusions from previous findings is the possibility that the exposure durations (of the target and distractor items) have been too brief for older adults to engage in whatever type of identification and encoding of distractors it is that ultimately enables inhibition to develop or be directed toward them. The slowed performance that is broadly characteristic of older adults (e.g., Madden, 1989; Plude & Hoyer, 1981; Salthouse, 1982, 1985, 1988) may make it a possible cause of older adults' failure to demonstrate reliable negative priming. Thus, in the second experiment, we substantially increased the exposure duration of the stimuli, to enable more extensive processing by older adults than may have been permitted in earlier work.

In an additional effort to learn whether or not older adults are able to identify distractors on selection trials, two other conditions (after Allport et al., 1985; Dalrymple-Alford & Budayr, .1966; Lowe, 1979) were included in our experiments: a condition in which the distractor item repeats across successive pairs of trials (called *repeated distractor)* and a condition in which the target item of the previous trial becomes the distractor item on the current trial (called *target to distractor).* Young adults show facilitation in both of these conditions, compared with a control condition without successive relationships (Allport et al., 1985; Lowe, 1979; Neill, 1978). Although there are several competing explanations for both repeated distractor and target-to-distractor effects (see Allport et al., 1985; Hinton, 1976; MacLeod, 1991; Neill, 1978; Tipper, Bourque, Anderson, & Brehaut, 1989), all of them are based on the assumption that knowledge about the current trial's distractor was gained by exposure to that item on the previous trial. The inclusion of these conditions in this study should help to clarify a potential source of the failure of older adults to show suppression in previous studies: They failed to identify (or recognize, or analyze) the distractor. Without distractor identification, there would be nothing to suppress. If older adults in the present study also failed to identify distractors, they could be expected to show no suppression and also to show no facilitation in the two new conditions. If, however, older adults showed facilitation on repeated distractor and target-to-distractor trials while still showing no negative priming, their lack of a negative priming effect could be taken as evidence of a deficient inhibitory mechanism.[2]

We explore two additional issues in this article. First, we investigate the relationship between suppression and everyday cognitive failures, failures such as forgetting the reason for having gone to a particular room. To measure the latter, we used the Cognitive Failures Questionnaire (CFQ; Broadbent, Cooper, FitzGerald, &

Parkes, 1982), a self-report measure thought to serve as an index of the relationship between attentional performance and general cognitive functioning (see Martin, 1983; Tipper & Baylis, 1987). Although the CFQ is not composed of reliable subscales that differentially tap attention versus memory failures, several studies have suggested the existence of a relationship between CFQ and laboratory performance in selective and divided attention tasks (Broadbent, Broadbent, & Jones, 1986; Harris & Wilkins, 1982; Martin & Jones, 1983). These studies indicated that subjects who reported fewer in-stances of cognitive failures tended to perform more efficiently on attention tasks than did those who reported more instances of cognitive failures. Furthermore, Tipper and Baylis (1987) found that young adult subjects who reported high frequencies of cognitive failure on the CFQ also showed lower levels of suppression than did low CFQ scorers. Given the frequent finding of age deficits in selective attention tasks (e.g., Madden, 1982, 1983; Plude & Hoyer, 1981), the generally higher frequency of memory complaints among older adults than among younger adults (e.g., Cavanaugh, 1986) and the apparent absence of suppression effects for older adults, one might expect to see higher CFQ scores for older than for younger adults, as well as a differential pattern of relationships among suppression, interference, and CFQ scores. To our knowledge, the present experiments represent the first time that the CFQ has been used to directly compare younger and older adults.

The final issue considered here is the nature of the relation-ship between inhibition (as measured by the degree to which subjects are slowed on suppression trials) and interference (as measured by the degree to which subjects are slowed by naming one stimulus in the presence vs. absence of a distractor). Some views (e.g., Tipper, 1991; Tipper & Baylis, 1987; Tipper et al., 1989) suggest that inhibition functions to reduce interference created by concurrently presented distractors. From this perspective, one would expect an inverse relationship between the size of the suppression effect and the extent of interference, at least for younger adults. Furthermore, one would expect that if older adults show no (or less) suppression, they also would show large (or larger) interference effects. Another view, however, suggests that inhibition operates not to reduce interference from concurrent sources of stimulation but rather to isolate the present stimulus situation from the previous one (Stoltzfus et al., 1993). According to this view, no relationship between suppression and concurrent interference is necessarily expected. In the hope that additional data may help clarify these alternative views, we included a measure of interference from distractors among the conditions in these experiments.

Experiment 1

The central goal in this experiment was to increase the size of the suppression effect seen for younger adults, in the interest of detecting a possibly smaller, but nonetheless reliable, effect for older adults. On the basis of pilot work, we made two key changes between the task we used earlier (Hasher et al., 1991; Stoltzfus et al., 1993) and the present one. The first change was in the materials, with a switch from single letters to familiar words. The second change was in list structure. Previous work (see also McDowd & Oseas-Kreger, 1991) had used a procedure in which subjects received alternating lists of blocked negative priming-type and control-type trials. Such blocking procedures sometimes lend themselves to participants' recognizing particular trial types, and that may, in turn, lead to alterations in response patterns that diminish suppression effects (Hasher et al., 1991; but see also Neill & Valdes, 1992). Here, we used a procedure in which experimental conditions were intermixed throughout the task.

Method

Design and subjects. The experimental design consisted of the between-subjects factor, Age (younger vs. older adults), and the within-subjects factor, Trial Type. There were five types of prime-test pairs: (a) control, in which neither word in the prime display was related to either word in the test display; (b) distractor suppression, in which the distractor in the prime display became the target in the test display; (c) repeated distractor, in which the distractor in the prime display remained the distractor in the test display; (d) target to distractor, in which the target in the prime display became the distractor in the test display; and (e) no distractor, in which the target in the test display appeared without a distractor and had no relationship to either word in the prime display. (See Table 1 for examples of these conditions.)

Forty young adults (mean age 18.9 years, range 17-25) were recruited from undergraduate psychology courses and participated for course credit. Thirty-seven older adults (mean age 69.5 years, range 62-78) were recruited from the subject pool maintained by the Duke University Center for the Study of Aging and Human Development and were paid $5 plus parking fees. One older subject was unable to complete the session. *Materials.* Nine three-letter nouns in full capitals served as the experimental stimuli (cat, pot, jar, tie, cup, fun, gin, bag, and rod). All words had frequencies between 10 and 50 per 1,000,000 words (Kucera & Francis, 1967). Furthermore, rhyming words, synonyms, and words such as *box* and *car,* which have meaning when presented together, were avoided, as were words that did not consistently trigger the voice key.

Subjects saw 180 trials, each consisting of two displays of one or two words (each word appearing above or below a fixation point), the first display being the prime and the second being the test display. There were 36 such paired trials in each of the five conditions that were presented pseudorandomly with the constraint that no condition occurred on more than three trials in a row. Within each condition, every stimulus word appeared four times in each possible function: prime target, prime distractor, test target, and test distractor (with the exception of the no-distractor condition, in which every word appeared four times as a prime target, prime distractor, and test target). Every possible combination of two words occurred twice in every experimental condition, with each item serving once as the target member and once as the distractor member of the pair and with one of these pairings occurring as a prime display and the other as a test display.

There were two stimulus lists, which differed only in the ordering of the identical prime-test word pairs. These lists were used equally often with each age group. No specific prime-test display combination occurred more than once in the entire stimulus list. Top or bottom positioning of the targets and distractors occurred randomly but equally often across prime-test displays and across conditions. Finally, no stimulus words from a particular test display appeared on the subsequent trial in the prime display, in order to avoid sequential effects between trials.

Two written tasks were also required of subjects, the Extended Range Vocabulary Test (ERVT), from the Kit of Factor-Referenced Cognitive Tests (Educational Testing Service, 1976) and the CFQ (Broadbent et al., 1982). The ERVT is a difficult, 48-item, multiple-choice vocabulary test that is given under time limitations; the CFQ (here presented to subjects as a "Minor Mistakes Questionnaire") is an untimed, 25-item, inventory measuring self-ratings of everyday lapses in cognitive performance (e.g., "Do you find you forget people's names?" "Do you drop things?" "Do you find you forget appointments?"). The CFQ is reliable, with test-retest correlations exceeding $r = .80$ at intervals of 21 and 65 weeks (Broadbent et *al.*, 1982).

Procedure. Subjects were tested individually in a dimly lit room where they were seated in front of a computer screen. Subjects were told that they would be presented with a series of two-word visual displays in which the word in one color was to be named while the word in the other color was to be ignored. Half of the subjects in each age group were instructed to name the red word, and half were instructed to name the green word.

The word pairs were presented at the center of a Mitsubishi color monitor that was controlled by a program executed on an IBM-compatible microcomputer with an 80286 processor and an Enhanced Graphics Adaptor card. Each word was 6 mm high and 22 mm wide. The word pair was presented as one word above the other, separated by a 2-mm space. Subjects sat at their most comfortable distance (between 35 and 75 cm) from the computer monitor. The visual angle subtended by the distance from the extreme upper edge of one word to the extreme lower edge of the other was between 0.46° and 0.84°; the horizontal visual angle was between 1.68° and 3.07°. The angle subtended by the distance between the two words was between 0.2° and 0.3°. Thus, the word displays were completely within foveal view for all subjects (Cerella, 1985).

Each subject briefly practiced using the voice-activated relay (by responding to visually presented digits), which was used to record the onset latency of the subject's verbal response to the target word. Next, the subject was read a set of instructions that included a sample trial's sequence of events. Each trial began with a ready signal (Ready?), which remained on the screen until the subject initiated the trial by pressing the keyboard's space bar.

After a 1,000-ms delay, there was a 250-ms presentation of a fixation cross in the center of the screen (i.e., with its horizontal bar in the 2-mm space between the upcoming stimulus words). Next, the words of the prime display were presented for 300 ms and were immediately masked for 100 ms by symbols consisting of overlapping red and green lines. A blank screen was presented for 1,500 ms following the offset of the prime mask. The test display sequence was automatically initiated by a fixation cross appearing for 250 ms. The test display was then presented for 300 ms and was masked for 100 ms, after which the subject responded. Thus, the interval between the offset of the prime word pair and the onset of the test display was 1,850 ms. Although this is a slightly longer interstimulus interval than has been used in the past (e.g., Allport et al., 1985; Tipper et al., 1989), it is similar to response-to-stimulus onset intervals that have elicited reliable suppression (Stoltzfus et al., 1993; Tipper, Weaver, Cameron, Brehaut, & Bastedo, 1991). Subjects were required to respond to both prime and target displays of each trial.

Table 1
Hypothetical Examples of Trial Type Conditions (Target Words in Bold Type)

Display	Trial type: Control	Distractor suppression	Repeated distractor	Target to distractor	No distractor
Prime	**CAT**	**CAT**	**CAT**	**CAT**	**CAT**
	POT	POT	POT	POT	POT
Test	**FUN**	**POT**	**FUN**	**FUN**	**FUN**
	GIN	GIN	POT	CAT	

Reaction time feedback for both the prime and test displays of each trial appeared after the subject's test trial response and remained on the screen for 3 s. Subjects were instructed to place equal emphasis on speed and accuracy and were told that the reaction time feedback was simply for their own benefit in maintaining a consistent speed of responding. No feedback was given regarding target-naming accuracy. The next prime trial was again initiated by the subject at the presentation of a ready signal, which immediately followed the reaction time feedback. Thus, intertrial intervals were controlled by the subject. Reaction times were recorded for all trials and were measured from the onset of the stimulus array to the onset of the subject's response. Errors in word naming and voice key failures were recorded by the experimenter.

After the word-naming task, subjects completed the CFQ and the ERVT and then were questioned about their awareness of the experimental conditions in the word-naming task. No subjects indicated awareness of the critical distractor suppression condition.[3]

Results

Subject comparisons. The data from 9 younger and 4 older adults with error rates greater than 25% either within a single condition or across all conditions were eliminated from the study. Five of the younger subjects and 1 of the older subjects were eliminated because a subset of reaction times in the no-distractor condition were faster than our apparatus was programmed to measure. (We were not able to measure responses occurring within the 300 ms of stimulus exposure.) Thus, the elimination of these very fast subjects probably underestimates the true interference effects for young adults. No conclusions regarding conditions other than the no-distractor condition (see subsequent results) were altered by the deletion of these subjects' data. All results reported here are for the remaining 31 younger and 32 older adults. Older adults scored significantly higher than did younger adults in ERVT vocabulary score (M = 32.9 and 26.6, respectively), $F(1, 61) = 10.54$, $MS_e = 60.06$. Older adults also had significantly more years of education than did younger adults (M = 15.4 and 12.8 years, respectively), $F(1, 61) = 40.38$, $MS_e = 2.64$.

Reaction time. The mean test trial reaction times in the word-naming task for each condition and age group are shown in Table 2. All trials on which an error was made on either a prime or a test display were eliminated from reaction time analyses. Errors were characterized by the following response types: failing to make any verbal response, naming incorrect targets, partial naming of incorrect targets, and stuttering while producing correct target names. Trials on which a voice key failure occurred (resulting from equipment malfunction, insufficient volume of responses, or excessively fast responses) also were considered errors. The mean percentage of deleted trials was 6.2 and 4.5 for younger and older subjects, respectively. Medians were calculated on the remaining test trial reaction times.

Although planned comparisons were the major mode of analysis, an omnibus 2 (Ages) X 5 (Trial Types) repeated-measures analysis of variance (ANOVA) was performed on reaction times to confirm general expectations. Here, and throughout, the significance level was set at $p = .05$ for all analyses. Older adults were slower than younger adults, $F(1, 61) = 55.62$, $MS_e = 25{,}564.56$. There were reliable differences among the experimental conditions, $F(4, 244) = 65.24$, $MS_e = 276.00$, and most important, there was a significant Age X Trial Types interaction, $F(4, 244) = 4.00$, $MS_e = 276.00$.

Planned comparisons were conducted separately within each age group. Younger adults were reliably slower on distractor-suppression trials than on control trials, $F(1, 30) = 13.05$, $MS_e = 784.78$, showing a suppression effect of 18 ms. In addition, younger adults were faster on target-to-distractor trials than on control trials, $F(1, 30) = 6.68$, $MS_e = 584.66$, showing a facilitation effect of 11 ms. Younger adults also were faster on no-distractor trials than on control trials, $F(1, 30) = 92.27$, $MS_e = 356.30$, showing an interference effect of 32 ms. The 4-ms facilitation effect on repeated-distractor versus control trials was not reliable, $F(1, 30) = 1.29$, $MS_e = 449.01$. Older subjects showed no reliable difference in reaction time between distractor-suppression and control trials, $F(1, 31) < 1$. Thus, although younger adults' negative priming effect in-creased from that reported in our previous work (Hasher et al., 1991; Stoltzfus et al., 1993), suppression was still not found for older adults. Nonetheless, older adults were reliably faster on target-to-distractor trials than on control trials, $F(1, 31) = 8.75$, $MS_e = 587.03$, with a facilitation effect of 13 ms. They also were faster on no-distractor trials than control trials, $F(1, 31) = 93.08$, $MS_e = 581.03$, showing an interference effect of 41 ms. Unlike younger adults, older adults also showed a reliable facilitation of 10 ms between repeated-distractor and control trial reaction time, $F(1, 31) = 8.71$, $MS_e = 738.14$, a finding similar to one reported by McDowd and Oseas-Kreger (1991). Note that older adults showed benefits (facilitation) on a test trial from information acquired on a prime trial, despite showing no negative priming effect.

Final comparisons contrasted the effect sizes (i.e., the difference scores) shown by younger adults with those shown by older adults; there was a reliable age difference in the distractor suppression effect (distractor suppression minus control), $F(1, 61) = 9.14$, $MS_e = 761.07$, but no reliable age differences were found in the repeated-distractor effect (repeated distractor minus control), $F(1, 61) = 1.24$, $MS_e = 406.45$, the target-to-distractor effect (target to distractor minus control), $F(1, 61) < 1$, or the interference effect (no distractor minus control), $F(1, 61) = 2.44$, $MS_e = 470.50$, the last of which indicated equivalent distractibility between ages due to the presence of nontarget items.'

Errors. The mean test trial error rates in the word-naming task for each trial condition and age group are shown in Table 2. Test trial error rates were also analyzed using planned comparisons within each age group after first determining that the overall age difference was not significant, $F(1, 61) = 2.88$, $MS_e = 0.01$, $p = .095$. Younger adults showed no reliable error rate difference between distractor-suppression trials and control trials, $F(1, 30) = 1.75$, $MS_e = 0.004$, or between repeated-distractor trials and control trials, $F(1, 30) = 3.04$, $MS_e = 0.01$. They made fewer errors on target-to-distractor trials than on control trials, $F(1, 30) = 11.36$, $MS_e = 0.01$ and, also, fewer errors on no-distractor trials than on control trials, $F(1, 30) = 5.19$, $MS_e = 0.01$.

Table 2

Mean Reaction Times, Standard Deviations, and Error Rates for Younger and Older Adults by Trial Type in Experiments 1 and 2

Experiment	Trial type: Control	Distractor suppression	Repeated distractor	Target to distractor	No distractor
Experiment 1					
Younger adults[a]					
M	542	560	538	531	510
SD	58.3	55.8	55.1	51.5	50.3
Error rate	0.078	0.093	0.056	0.036	0.048
Older adults[b]					
M	684	681	674	671	643
SD	85.8	90.8	85.8	93.1	81.2
Error rate	0.057	0.071	0.050	0.035	0.014
Experiment 2					
Older adults[c]					
M	661	665	646	648	611
SD	76.3	72.2	73.0	79.9	74.6
Error rate	0.038	0.049	0.033	0.017	0.004

[a] $n = 31$. [b] $n = 32$. [c] $n = 20$.

Older adults showed no reliable difference in error rates between distractor-suppression trials and control trials, $F(1, 31) = 1.31$, $MS_e = 0.01$, and between repeated-distractor and control trials, $F(1, 31) < 1$. They made reliably fewer errors on target-to-distractor trials than on control trials, $F(1, 31) = 4.04$, $MS_e = 0.004$, as well as fewer errors on no-distractor trials than on control trials, $F(1, 31) = 15.92$, $MS_e = 0.004$. The error rates of both age groups ran largely parallel to the patterns of their reaction time data, and no effects appeared to be compromised by speed/accuracy trade-offs.

Correlational analyses of effects. As a test of the relation-ship between the ability to inhibit a previous distractor and the ability to avoid interference from a concurrent distractor, correlations between the suppression effect and the interference effect were obtained within each age group. Response time effect scores were calculated for each subject (by subtracting the median distractor-suppression or no-distractor reaction times from control trial reaction time) and were then correlated with each other. Both younger and older adults produced significant negative correlations between suppression and interference scores (for younger adults, $r = -.584$, $p < .01$, and for older adults, $r = -.531$, $p < .01$). Inspection of the scatter plots revealed, in each instance, two outlying subjects whose performances seemed to skew the distribution. A recalculation done after removing the two outlying subjects in each age group reduced the correlations substantially in each case to (a nonsignificant) -.248 and (a still significant) -.561 for younger and older adults, respectively.[5]

In the absence of a priori predictions, repeated-distractor difference scores (repeated distractor minus control) and target-to-distractor difference scores (target to distractor minus control) were correlated with each other and with the distractor-suppression and interference difference scores. Again, inspection of the scatterplots revealed that the removal of one to two outliers in each instance reduced reliable correlations to non-significant ones (this is not too surprising, given the small *n* and the use of difference scores). Table 3 thus shows all of the correlations with outliers removed. Note first that the suppression effect was not significantly correlated with any other measures for either age group.

The young subjects' data indicated reliable correlations between the repeated-distractor effect and the target-to-distractor effect ($r = .435$) and between the interference effect and both the repeated-distractor effect ($r = -.581$) and the target-to-distractor effect ($r = -.749$). For older subjects, the only reliable correlation was the interference effect with the repeated-distractor effect ($r = -.378$). Thus, for both older and younger subjects, there was a tendency for higher levels of interference to be associated with greater repeated-distractor facilitation; for younger subjects, higher interference also seemed to predict greater target-to-distractor facilitation. A correlation between repeated-distractor and target-to-distractor effects was found only in the younger subjects' data.

Table 3
Correlation Matrices for Reaction Time Difference Scores for Younger and Older Adults in Experiments 1 and 2 With Outliers Removed

Experiment	Distractor suppression	Repeated distractor	Target to distractor
Experiment 1			
Younger adults			
Repeated distractor	.277	—	
Target to distractor	.307	.435*	—
Distractor interference	−.248	−.581*	−.749*
Older adults			
Repeated distractor	.152	—	
Target to distractor	.313	.294	—
Distractor interference	−.361*	−.378*	−.272
Experiment 2			
Older adults			
Repeated distractor	.140	—	
Target to distractor	.296	.294	—
Distractor interference	−.498*	−.129	−.335

*$p < .05$.

Although relationships such as these may someday prove in-formative and interesting, we argue that strong conclusions should not be drawn from the present correlational analyses, because of their instability. For example, more than half of the correlations in the data set that were originally reliable were no longer significant after the removal of just one or two outlying subjects. Clearly, a larger subject pool would be necessary to convincingly establish the nature of the relationships between these various reaction time effects.

Cognitive failures. There was a marginal difference in CFQ scores between younger and older adults, with younger subjects indicating slightly more (45.6) failures than older subjects (41.3), $F(1, 61) = 3.27$, $MS_e = 89.09$, $p = .08$. Neither younger nor older subjects showed reliable correlations between their CFQ scores and suppression (r = -.128 and -.138, respectively) or between CFQ scores and interference (r = -.161 and .130, respectively).

Discussion

Consistent with the results of previous negative priming studies, we found reliable suppression effects for younger but not for older adults (Hasher et al., 1991; McDowd & Oseas-Kregar, 1991; Stoltzfus et al., 1993; Tipper, 1991). Furthermore, the present methodology effectively doubled the size of the suppression effect for younger adults (Hasher et al., 1991; Stoltzfus et al., 1993), while still detecting no reliable effect for older adults. Thus, the lack of suppression shown by older adults in previous studies can be replicated in a more sensitive experimental context. The conclusion that older adults either cannot engage in suppression or else have greater difficulty in doing so than do younger adults is here strengthened by the fact that, like younger adults, older adults do show other sequential effects. Thus, in-sensitive measurement problems are an unlikely explanation of the failure to see suppression for older adults in the present investigation.

The patterns of findings across the remaining experimental conditions used in this investigation can be taken as evidence against the strawman argument that older adults fail to show suppression because they learn virtually nothing about the distractor on any given trial, or that, even if they know something about the distractor, they cannot use what they know in any way. First, older adults were faster on trials in which the new distractor was also the previous distractor (repeated distractor), as compared with control trials in which there was no sequential relationship among the items. Second, older adults were faster on test trials in which the current distractor had been the previous target (target to distractor), again as compared with control trials. Along with significant interference effects, these data together suggest that older adults do indeed identify and process distractor items on a concurrent trial (interference effect) and that this identification process can be carried over to the next trial to facilitate performance. Nonetheless, older adults fail to engage inhibitory mechanisms to a rejected distractor.

The no distractor—control condition comparisons failed to reveal a reliable age difference in interference, as was also the case in Stoltzfus et al. (1993). This finding is, however, inconsistent with other work (McDowd & Oseas-Kreger, 1991; Tipper, 1991) that found greater interference for older adults. The source of these discrepancies is unclear. Discussion of the finding of an association between the ability to suppress distractors and the ability to avoid interference from distractors (for both younger and older adults) is deferred to the end of Experiment 2.

The facilitation effect young adults showed here on repeated-distractor trials is not as robust as that which has been seen previously (Allport et al., 1985; McDowd & Oseas-Kreger, 1991; Tipper et al., 1989; Tipper & Cranston, 1985). These studies all used blocks of trials comprising a single condition in which a specific distractor (or at least the specific repeated-distractor trial type) repeats for many displays (but see Lowe, 1979). In the current procedure, however, the repeated-distractor trial type could not appear on more than three consecutive trials, and any particular distractor word could only repeat from a single prime to a single test display. Thus, it may be that substantial facilitatory benefits associated with a repeating distractor require a larger number of repetitions than were used here.

Although we note that our own post hoc comparisons indicated no reliable age differences in repeated-distractor facilitation, our results are in the same direction as previous findings that have showed greater repeated-distractor facilitation for older adults and children than for younger adults (McDowd & Oseas-Kreger, 1991; Tipper et al., 1989). Tipper et al. (1989) proposed a dissociation between distractor suppression and repeated-distractor facilitation, the latter of which they attributed to a passive habituation process in which repeatedly presented distractors cease to evoke an orienting response. Subsequently, McDowd and Oseas-Kreger (1991) speculated that, unlike inhibitory mechanisms, these habituation processes may remain stable across the life span. Our results do not appear to contradict their position.

Our finding of a target-to-distractor facilitation effect for both age groups is somewhat more difficult to explain. Although competing hypotheses about this effect are numerous (Hinton, 1976; Neill, 1978; E. Neumann & DeSchepper, 1991; see Mac-Leod, 1991, for a review), none can clearly or consistently ac-count for all of the data. Thus, we offer the following post hoc suggestion: The facilitation found here may have resulted from subjects' sensitivity to the current experimental context. That is, in our study (in contrast with others, e.g., Dalrymple-Alford & Budayr, 1966; Lowe, 1979; E. Neumann & DeSchepper, 1991) there were no trials in which a previous target was a candidate for a subsequent response. Thus, if a target reoccurred on a subsequent display, it was always a distractor, possibly enabling both younger and older adults to reject as a candidate for response a distractor that was recognized as having served as a target on the preceding trial more easily than to reject a new distractor. We also note that studies that have, in fact, included a condition in which targets can repeat across trials have failed to find reliable target-to-distractor facilitation.

Only a marginal age difference was found in self-ratings of general cognitive lapses, as indexed by the CFQ. These results are loosely consistent with a study by Rabbitt and Abson (1990; see also Rabbitt, 1990), which found no age differences in CFQ scores among adults in their 60s, 70s, and 80s but which also found fewer reported lapses by these subjects than by a group of 50-year-olds.

The cognitive lapse results reported here are, however, inconsistent with those of Tipper and Baylis (1987), which suggested a relationship among CFQ, suppression, and interference measures. No reliable effects were found here. Similar to Rabbitt and Abson (1990), our results tentatively suggest that subjective ratings of cognitive performance may be of limited (or at least, inconsistent) value in assessing between-group differences or in predicting performance in certain laboratory tasks.

Experiment 2

Although the data from the first experiment clearly suggest that older adults learned something about distractors, they nevertheless failed to engage inhibition. This might be because they are reliably slower than younger adults on virtually all tasks, including the present one. We note that in most suppression studies and in all but one involving older adults (McDowd & Oseas-Kreger, 1991, in which exposure duration was controlled by the subjects rather than by the experimenter), the critical stimulus display has been exposed for relatively brief durations, typically ranging from approximately 100 ms to approximately 300 ms. It is possible that these durations were simply too brief for older adults to encode whatever critical information about distractors is needed to engage inhibitory mechanisms. Or, per-haps the exposure duration was too brief to both code the information and to engage suppression. So, in this experiment, we increased the exposure duration of the paired stimuli in a replication of the first study and tested only older adults.

Method

Twenty older adults who had not participated in the first study were tested, using the task, materials, and procedures from Experiment 1. Subjects were recruited and paid as before. The major change between studies was the stimulus exposure duration, which was increased from 300 ms to 500 ms. In addition, the apparatus was now able to measure any responses that occurred during stimulus exposure.

Results and Discussion

Subjects. The mean age of the subjects was 70.4 years (range 64-77) and they averaged 15.8 years of education. The mean score for the ERVT was 33.79. These values do not differ from those reported for participants in the first study, $F(1, 50) = 1.62$, $MS_e = 11.528$ for age, $F(1, 50) < 1$ for years of education, and $F(1, 50) < 1$ for vocabulary score.

Reaction time. The means of median test reaction times are shown in Table 2. A one-way repeated-measures ANOVA on trial types confirmed the presence of differences among conditions, $F(4, 76) = 17.20$, $MS_e = 521.79$. As in Experiment 1, planned comparisons were used to test for critical effects. Older subjects showed no reliable difference in reaction time between distractor-suppression and control trials ($F < 1$). Also similar to Experiment 1, subjects were faster on repeated-distractor trials than on control trials, $F(1, 19) = 6.60$, $MS_e = 704.57$, with a facilitation effect of 15 ms. Although the difference between target-to-distractor and control conditions was 13 ms in both studies, in this case this difference was no longer significant, $F(1, 19) = 2.30$, $MS_e = 1{,}366.419$, $p = .15$. Finally, subjects were faster on no-distractor than on control trials, $F(1, 19) = 39.00$, $MS_e = 1{,}261.62$, showing an interference effect of 50 ms. The central empirical question here was whether or not an increased exposure duration would enable older adults to show suppression. It clearly did not.

Errors. The mean test trial error rate for each condition also is shown in Table 2. Target-naming error rates were defined as in Experiment 1 and were analyzed as were the reaction times.

There was an overall difference in error rates among trial types, $F(4, 76) = 6.33$, $MS_e = 0.001$. Planned contrasts revealed patterns similar to those found in Experiment 1, with older subjects showing no reliable differences in number of errors between distractor-suppression trials and control trials and between repeated-distractor trials and control trials (Fs < 1). Also as in Experiment 1, older adults made fewer errors on target-to-distractor trials than on control trials, $F(1, 19) = 12.43$, $MS_e = 0.002$, and fewer errors on no-distractor trials than on control trials, $F(1, 19) = 15.19$, $MS_e = 0.002$. Thus, the present results appear not to be compromised by speed/accuracy trade-offs.

Correlational analyses of effects. As in Experiment 1, simple correlations were obtained between suppression and interference effects to test for a relationship between the ability to suppress and the ability to avoid interference. Older adults again showed a significant negative correlation ($r = -.498$). Subjects who demonstrated high levels of interference tended to show stronger facilitation effects on distractor-suppression trials. There were no other reliable correlations between effect scores (see Table 3).

Cognitive failures. The mean CFQ score was 36.3. There was a marginally significant difference in CFQ score between the older adults in Experiment 1 (mean of 41.3) versus in Experiment 2, $F(1, 50) = 3.94$, $MS_e = 3{,}927.08$, $p = .053$. Nonetheless, both of the correlations between CFQ score and the magnitude of the suppression effect ($r = -.206$), and the size of the interference effect ($r = .114$), were nonsignificant (the smallest $p > .30$).

Cross-experiment comparisons. To determine whether older adults produced reliably different reaction time patterns with an increased stimulus duration, a 2 X 5 repeated-measures ANOVA was performed with Experiment or Exposure Duration (300 ms vs. 500 ms) and Trial Type as factors. There was no main effect of Exposure Duration, $F(1, 50) = 1.10$, $MS_e = 32{,}894.93$. There were reliable differences among Trial Types, $F(4, 200) = 44.12$, $MS_e = 389.98$; however, there was no reliable Exposure Duration X Trial Type interaction, $F(4, 200) = 1.11$. Thus, the patterns of effects for the two Exposure Duration groups were not reliably different. Planned comparisons revealed that the facilitation effects seen in the target-to-distractor condition, $F(1, 51) = 9.57$, $MS_e = 866.13$, and the repeated-distractor condition, $F(1, 51) = 15.24$, $MS_e = 492.09$, were both significant, as was the interference effect, $F(1, 51) = 121.93$, $MS_e = 840.15$. Particularly noteworthy is the fact that even with the increased power available here, the suppression effect remained nonsignificant ($F < 1$).

Older subjects in both experiments showed a negative relation between the ability to suppress distractors from the previous trial and the ability to avoid interference from distractors from a concurrent trial. This same relationship for younger subjects was no longer significant when two outlying subjects were excluded from analysis. In contrast, older and younger subjects from Experiment 1 produced statistically equivalent interference effects. These findings, then, take their place among a literature in which a reliable negative relationship between suppression and interference effects sometimes is found (e.g., Beech, Baylis, Smithson, & Claridge, 1989; Tipper & Baylis, 1987) and sometimes is not (Beech & Claridge, 1987; Flowers, Heppner, & Muraoka, 1990; Stoltzfus et al., 1993).

If the role of attentional inhibition is in fact to reduce interference from concurrent distractors, one would predict an age difference in interference effects: Because older adults do not inhibit distractors as well as younger adults, older adults should be more adversely affected by their presence. A recent proposal by Stoltzfus et al. (1993), however, has suggested that the function of inhibition may not be to aid concurrent selection; rather, inhibition may act to maintain attention along an already-selected train of thought by preventing attention from returning to previously rejected stimuli. Although a deficient inhibitory mechanism of this type might predict the age deficits found in tasks requiring forgetting or abandoning thoughts that once were relevant but no longer are (Hamm & Hasher, 1992; Hartman & Hasher, 1991), it would not necessarily predict age differences in selection efficiency per se. In fact, the results from Stoltzfus et al. (1993) were similar to those reported here; specifically, older and younger adults did not differ in their susceptibility to interference from concurrently presented distractors.

General Discussion

The failure of the current studies to find suppression by older adults lends further support to a growing body of work indicating age differences in attentional inhibition (Hasher et al., 1991; McDowd & Oseas-Kreger, 1991; Stoltzfus et al., 1993; Tipper, 1991). In addition, the present investigations rule out several methodological considerations that might limit the generality of previous findings. First, the materials and procedure used in Experiment 1 substantially increased the magnitude of the suppression effect seen for younger subjects, compared with earlier work. Nonetheless, older adults still failed to show reliable suppression. Furthermore, in an effort to give older subjects more time to process the visual display, we used a considerably lengthened stimulus exposure duration in Experiment 2. This manipulation also failed to produce, or enable, suppression by older subjects. These findings suggest that previous results were not the artifacts of limited methodologies and that the indices of aging deficits in attentional inhibition are indeed robust.

In addition, findings of facilitation on repeated-distractor and target-to-distractor conditions indicated that older adults can be affected by trial types involving sequential relationships between prime and test display stimuli, if not by the relationship on distractor-suppression trials. These findings indicate that the lack of suppression in older adults cannot be attributed to their total failure to process distractor information. They indicate as well that experimental insensitivity is an unlikely explanation of the failure to see a negative priming effect for older adults.

Aspects of the present data also speak to a recently proposed alternative explanation of the negative priming effect. Neill and Valdes's (1992) episodic retrieval hypothesis suggests that response latencies on distractor-suppression trials increase not because of inhibition applied to the previous distractor but rather as a result of the mismatch between codes created on successive trials. That is, on a given trial *n*, display items are automatically encoded by the subject according to their attributes, their identities, their status as relevant (targets) or irrelevant (distractors), and the response they require (e.g., name it vs. ignore it). Because trial *n* + 1 occurs in a similar context, it automatically6 initiates the retrieval of trial *n;* subjects slow down because the item coded as a target to be named on trial *n + 1* was coded as a distractor to be ignored on trial *n*. Neill and Valdes (1992) argued that it is conflict between retrieval episodes that causes the negative priming effect, rather than any inhibition directed toward the identity of the previous distractor. If the argument that negative priming is due to episodic retrieval is correct, then the failure of older adults to show a suppression effect could be attributed either to their failure to effectively encode each trial episode, or to their failure to successfully retrieve previously learned episodic information, or to both.

Note that according to the episodic retrieval view, target-to-distractor trials should also cause a slowdown, at least for younger adults (who presumably are good retrievers), because of the conflict between retrieval episodes (i.e., the target on trial *n* has a name-it tag vs. an ignore-it tag on trial *n* 1). By this general argument, older adults who do not show a negative priming effect should also fail to show a facilitation effect for target-to-distractor trials, as they presumably either fail to learn the potentially conflicting information on the previous trial or they fail to correctly retrieve the previous trial.

Thus, if mismatches between retrieval episodes were responsible for the slowdown young adults exhibited on distractor-suppression trials, a similar slowdown should also have occurred on target-to-distractor trials, in which a previously relevant target became an irrelevant distractor. As evidenced here, young adults showed the opposite pattern; like older adults, they demonstrated a significant facilitory effect (see Neill, 1978, for comparable findings with young adults). It is unclear how an episodic retrieval view can account for these findings; Neill and Valdes (1992) suggested no reason why one type of code or response tag mismatch should cause a slowdown while another should cause a speedup. Furthermore, because older and younger adults demonstrated the same facilitory patterns of target-to-distractor effects, a compromise in episodic retrieval (or encoding) of a target-distractor function cannot easily account for the absence of suppression in older adults. Thus, the data from older adults help to suggest that the slowdown young adults showed here (and throughout a large literature) for trials on which the new target had been the previous distractor is indeed due to an inhibitory mechanism, one which, for older adults, is clearly impaired.

Recent evidence reported by Connelly (1992; Connelly & Hasher, 1993) suggests strongly that the inhibitory deficit shown by older adults is not universal across all attributes of an item (e.g., Underwood, 1969). Connelly's research clearly showed age-preserved suppression of the location of a previous distractor coupled with age-impaired suppression of the distractor's identity. Thus, an age-related inhibitory deficit may instead be limited to an item's identity. These data strongly suggest that not all inhibitory mechanisms are impaired with age. Nonetheless, the age-related loss, or malfunctioning, or inefficiency of inhibitory mechanisms directed toward the identity of distractors has, as Hasher and Zacks (1988) argued, extremely important consequences across a range of behaviors in which the identity of objects and thoughts is important, including aspects of memory and language.

Notes:

1 The terms *suppression* and *negative priming* refer to the slowdown seen on distractor suppression trials relative to control trials, and the term *inhibition* refers to the hypothesized attentional mechanism presumed responsible for this slowdown.

2 Although these trial type conditions were employed here primarily as diagnostic measures, results from these conditions also will be discussed in relation to a recent theory of negative priming advanced by Neill and Valdes (1992).

3 A small number of subjects were aware of the repeated-distractor condition, but these subjects produced data similar to unaware subjects.

4 Note that the present estimate of interference for younger adults (32 ms) is possibly an underestimate of their true interference because of the elimination of those young subjects (12% of the initial sample) whose responses on a proportion of the no-distractor trials were too fast (< 300 ms) for us to measure. However, to the extent that the eliminated subjects were also faster than the average of the other young subjects on the control trials, their elimination probably had a small impact on the overall estimate of the interference effect in the young group.

5 Because these correlations were based on difference scores, a partialing method suggested by Glenberg (1990) and also used in Stoltzfus et al. (1993) was used on the present data. No conclusions were altered.

6 The argument of the automatic retrieval of episodes is based on Logan's (1988) instance theory of automatization, but its application to the negative priming paradigm may be problematic. Logan (1988) suggested that in a varied mapping task, in which individual items are used as both targets and distractors, retrieval of individual traces should pro-vide little useful information, so subjects should ignore these traces and respond on the basis of an algorithm (e.g., select on the basis of the current display). Because negative priming tasks, by definition, use the same stimuli as targets and distractors, it is unclear why subjects would be affected by the automatic retrieval of previous trial episodes, even if that retrieval were certain to take place.

References

Allport, D. A., Tipper, S. P., & Chmiel, N. (1985). Perceptual integration and post-categorical filtering. In M. I. Posner & O. S. M. Marin (Eds.), *Attention and performance XI* (pp. 107-132). Hillsdale, NJ: Erlbaum.

Beech, A., Baylis, G., Smithson, P., & Claridge, G. (1989). Individual differences in schizotypy as reflected in measures of cognitive inhibition. *British Journal of Clinical Psychology 28,* 117-129.

Beech, A., & Claridge, G. (1987). Individual differences in negative priming: Relations with schizotypal personality traits. *British Journal of Psychology, 28,* 110-116.

Broadbent, D. E. (1982). Task combination and selective intake of in-formation. *Acta Psychologica, 50,* 253-290.

Broadbent, D. E., Broadbent, M. H. P., & Jones, J. J. (1986). Performance correlates of self-reported cognitive failure and obsessionality. *British Journal of Clinical Psychology, 25,* 285-299.

Broadbent, D. E., Cooper, P. F., FitzGerald, P., & Parkes, K. R. (1982). The Cognitive Failure Questionnaire (CFQ) and its correlates. *British Journal of Clinical Psychology, 21,* 1-16.

Cavanaugh, J. C. (1986). Age differences in adults' self-reports of memory ability: It depends on how and what you ask. *International Journal of Aging and Human Development, 24,* 271-277.

Cerella, J. (1985). Age-related decline in extrafoveal letter perception. *Journal of Gerontology, 40,* 727-736.

Connelly, S. L. (1992). *Investigations of the relationship between aging and the suppression of spatial location.* Unpublished doctoral dissertation, Duke University, Durham, NC.

Connelly, S. L., & Hasher, L. (1993). Aging and the inhibition of spatial location. *Journal of Experimental Psychology: Human Perception and Performance, 19,* 1238-1250.

Connelly, S. L., Hasher, L., & Zacks, R. T. (1991). Age and reading: The impact of distraction. *Psychology and Aging, 6,* 533-541.

Dalrymple-Alford, E. C., & Budayr, B. (1966). Examination of some aspects of the Stroop color-word test. *Perceptual and Motor Skills*, 23,1211-1214.
Educational Testing Service. (1976). *Kit of factor-referenced cognitive tests.* Princeton, NJ: Author.
Flowers, J. H., Heppner, C. C., & Muraoka, T. J. (1990, November). *Negative priming and other attention measures as indices of individual differences.* Paper presented at the meeting of the Psychonomic Society, New Orleans, LA.
Gerard, L., Zacks, R. T., Hasher, L., & Radvansky, G. A. (1991). Age deficits in retrieval: The fan effect. *Journal of Gerontology: Psychological Sciences, 46,* P131-P136.
Glenberg, A. M. (1990). Common processes underlie enhanced recency effects for auditory and changing-state stimuli. *Memory & Cognition, 18,* 638-650.
Hamm, V. P., & Hasher, L. (1992). Age and the availability of inferences. *Psychology and Aging, 7,* 56-64.
Harris, J. E., & Wilkins, A. J. (1982). Remembering to do things: A theoretical framework and an illustrative experiment. *Human Learning, 1,* 123-136.
Hartman, M., & Hasher, L. (1991). Aging and suppression: Memory for previously relevant information. *Psychology and Aging,* 6,587-594. Hasher, L., Stoltzfus, E. R., Zacks, R. T, & Rypma, B. (1991). Age and inhibition. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 17,* 163-169.
Hasher, L., & Zacks, R. T. (1988). Working memory, comprehension, and aging: A review and a new view. In G. G. Bower (Ed.), *The psychology of learning and motivation* (Vol. 22, pp. 193-225). San Diego, CA: Academic Press.
Hinton, W. M., Jr. (1976). The effects of the number and spacing of base item repetitions on reaction time to Stroop-like stimuli. *Dissertation Abstracts International, 37,* 1005B.
Kucera, H., & Francis, W. N. (1967). *Computational analysis of present-day American English.* Providence, RI: Brown University Press. LaBerge, D. L. (1983). Spatial extent of attention to letters and words. *Journal of Experimental Psychology: Human Perception and Performance, 9,* 371-379.
Logan, G. D. (1988). Toward an instance theory of automatization. *Psychological Review, 95,* 492-527.
Lowe, D. G. (1979). Strategies, context and the mechanisms of response inhibition. *Memory & Cognition,* 7,382-389.
MacLeod, C. M. (1991). Half a century of research on the Stroop effect: An integrative review. *Psychological Bulletin, 109,* 163-203. Madden, D. J. (1982). Age differences and similarities in the improvement of controlled search. *Experimental Aging Research, 8,* 91-98.
Madden, D. J. (1983). Aging and distraction by highly familiar stimuli during visual search. *Developmental Psychology, 19,* 499-507. Madden, D. J. (1989). Visual word identification and age-related slowing. *Cognitive Development, 4,* 1-29.
Martin, M. (1983). Cognitive failure: Everyday and laboratory performance. *Bulletin of the Psychonomic Society, 21,* 97-100.
Martin, M., & Jones, G. V. (1983). Distribution of attention in cognitive failure. *Human Learning, 2,* 221-226.
McDowd, J. M., & Oseas-Kreger, D. M. (1991). Aging, inhibitory processes, and negative priming. *Journal of Gerontology: Psychological Sciences, 46,* P340-P345.
Navon, D. (1989a). The importance of being visible: On the role of attention in a mind viewed as an anarchic intelligence system. I. Basic tenets. *European Journal of Cognitive Psychology, 1,* 191-213.
Navon, D. (1989b). The importance of being visible: On the role of attention in a mind viewed as an anarchic intelligence system. II. Application to the field of attention. *European Journal of Cognitive Psychology, I,* 215-238.
Neill, W. T. (1977). Inhibitory and facilitory processes in selective attention. *Journal of Experimental Psychology: Human Perception and Performance, 3,* 444-450.
Neill, W. T (1978). Decision processes in selective attention: Response priming in the Stroop color-word task. *Perception and Psychophysics, 23,* 80-84.
Neill, W. T, & Valdes, L. A. (1992). Persistence in negative priming: Steady state or *decay? Journal of Experimental Psychology: Learning, Memory, and Cognition, 18,* 565-576.
Neumann, E., & DeSchepper, B. G. (1991). Costs and benefits of target activation and distractor inhibition in selective attention. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 17,* 1136-1145.

Neumann, O. (1987). Beyond capacity: A functional view of attention. In H. Heuer & A. F. Sanders (Eds.), *Perspectives on perception and action* (pp. 361-394). Hillsdale, NJ: Erlbaum.

Plude, D. J., & Hoyer, W. J. (1981). Adult age differences in visual search as a function of stimulus mapping and processing loads. *Journal of Gerontology,* 36,598-604.

Rabbitt, P. (1990). Age, IQ and awareness, and recall of errors. *Ergonomics, 33,* 1291-1305.

Rabbitt, P., & Abson, V. (1990). 'Lost and found': Some logical and methodological limitations of self-report questionnaires as tools to study cognitive ageing. *British Journal of Psychology 81*, 1-16.

Salthouse, T. A. (1982). *Adult cognition: An experimental psychology of human aging.* New York: Springer-Verlag.

Salthouse, T. A. (1985). Speed of behavior and its implications for cognition. In J. E. Birren & K. W. Schaie (Eds.), *Handbook of the psychology of aging* (2nd ed., pp. 400-426). New York: Van Nostrand Reinhold.

Salthouse, T. A. (1988). The role of processing resources in cognitive aging. In M. L. Howe & C. J. Brainerd (Eds.), *Cognitive development in adulthood* (pp. 185-239). New York: Springer-Verlag.

Shaw, R. J., Rypma, B., & Tale, C. E. (1992, March). *The effects of environmental support on age differences in ignoring distraction in reading.* Paper presented at the Cognitive Aging Conference, Atlanta, GA.

Stoltzfus, E. R. (1992). *Aging and breadth of availability during lan-guage processing.* Unpublished doctoral dissertation, Duke University, Durham, NC.

Stoltzfus, E. R., Hasher, L., Zacks, R. T., Ulivi, M. S., & Goldstein, D. (1993). Investigations of inhibition and interference in younger and older adults. *Journal of Gerontology: Psychological Sciences, 48,* P179-P188.

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

Tipper, S. P. (1991). Less attentional selectivity as a result of declining inhibition in older adults. *Bulletin of the Psychonomic Society, 29,* 45-47.

Tipper, S. P., & Baylis, G. C. (1987). Individual differences in selective attention: The relation of priming and interference to cognitive failure. *Personality and Individual Differences, 8,* 667-675.

Tipper, S. P., Bourque, T. A., Anderson, S. H., & Brehaut, J. C. (1989). Mechanisms of attention: A developmental study. *Journal of Experimental Child Psychology, 48,* 353-378.

Tipper, S. P., & Cranston, M. (1985). Selective attention and priming: Inhibitory and facilitatory effects of ignored primes. *The Quarterly Journal of Experimental Psychology, 37A,* 591-611.

Tipper, S. P., Weaver, B., Cameron, S., Brehaut, J. C., & Bastedo, J. (1991). Inhibitory mechanisms of attention in identification and localization tasks: Time course and disruption. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 17,* 681-692.

Treisman, A. (1986). Features and objects in visual processing. *Scientific American, 255,* 106-115.

Underwood, B. J. (1969). Attributes of memory. *Psychological Review, 76,* 559-573.