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Age-Related Equivalence of Identity Suppression in the Stroop Color–Word Task

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Previous failures to find reliable identity suppression (identity negative priming) in older adults have led to conclusions that older adults suffer from an impairment in the inhibitory component of selective attention. Here, 2 experiments using the Stroop procedure found identity suppression in older adults that was both reliable and equivalent to that in younger adults. Experiment 1 with repeated target colors produced correlations consistent with an episodic retrieval explanation of identity suppression. Experiment 2 without repeated targets produced correlations inconsistent with the episodic retrieval interpretation. These patterns were found for both younger and older adults. No evidence was found for reduced identity suppression that would be consistent with a general inhibitory impairment in older adults.

Selecting a target for processing can, in theory, be accomplished by facilitating the processing of the target information, inhibiting the processing of irrelevant, distracting information, or both (e.g., Houghton & Tipper, 1994; LaBerge & Brown, 1989). Facilitation is relatively unaffected by advancing age (for reviews see, e.g., Hartley, 1992; Madden & Plude, 1993). By contrast, it has been proposed that the inhibitory component of selection is impaired in older adults (e.g., Kane, Hasher, Stoltzfus, Zacks, & Connelly, 1994). The principal evidence for impaired inhibition in older adults comes from procedures that produce *identity suppression* or *identity negative priming*. In these procedures, a target and a distractor are presented on each trial. On critical pairs of trials, the distractor from one trial becomes the target on the subsequent trial. Responses on the subsequent trial are slowed relative to the second in a pair of trials in which the distractors and targets on adjacent trials are unrelated. The presumption has been that the identity of the distractor has been inhibited to aid selection of the concurrent target, but that inhibition persists and affects the processing of the subsequent target. The modal finding is that younger adults show a small but reliable suppression effect, whereas older adults do not (Hasher, Stoltzfus, Zacks, & Rypma, 1991; Kane, Hasher, et al., 1994; McDowd & Oseas-Kreger, 1991; Stoltzfus, Hasher, Zacks, Ulivi, & Goldstein, 1993; Tipper, 1991; also see Fox, 1995, and May, Kane, & Hasher, 1995, for recent comprehensive reviews of negative priming). Typically, the stimuli consist of pairs of letters, words, or pictures of everyday objects.

Three recent reports, however, have found not only reliable identity suppression but also equivalent suppression in older and younger adults (Kramer, Humphrey, Larish, Logan, & Strayer, 1994; Sullivan & Faust, 1993; Sullivan, Faust, & Balota, 1995). Sullivan and Faust (1993) and Sullivan et al. (1995) presented overlapping line drawings of common objects. Observers were to identify the object in one color and ignore the object in a different color. Previous comparisons of younger and older adults had used predominantly nonoverlapping stimuli. The overlapping line drawings may have been sufficiently difficult to disentangle perceptually and to identify that the older adults processed the distractors more completely than did older adults faced with simpler discriminations. (McDowd and Oseas-Kreger, 1991, used overlapping letters in different colors and reported lower identity suppression in older adults, but the letters may still have been relatively easy to disentangle and identify.) Kramer et al. (1994) presented displays with one target and three (identical) distractors at the corners of an imaginary diamond. The target was identified by a bar marker. Because the bar marker was not highly salient, it is likely that the observer would scan one or more distractors before locating the target. (Presenting the bar marker in advance eliminated the identity suppression effect and did so both for younger and older adults.) In all of these experiments, it was highly likely that the distractor was processed extensively; whereas in other experiments on identity supression, that may have been less true. More complete processing of a distracting stimulus on one trial could be expected to result in a greater effect of that stimulus on the next trial. A plausible hypothesis, then, is that situations that elicit substantial processing of distracting information will produce reliable identity suppression in older adults. Kramer et al. (1994) offered a similar hypothesis, speculating that selection of the target was more difficult in the studies that have found negative

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priming in older adults than it was in studies that have not found such effects.

The Stroop (1935) procedure provides an ideal test for this hypothesis. The task is to name the color in which a stimulus appears. In the critical conditions of the Stroop procedure, the colored stimuli are themselves color words. The words name colors that may be the same as the color in which the word appears (color and word are *congruent*, e.g., *blue* displayed in blue) or that may be different (color and word are *incongruent*, e.g., *blue* in red). The Stroop effect, the difference between reaction times on incongruent and congruent trials, is reliable and large, indicating that the distractor is processed.[1] Moreover, the effect is reliably larger in older than in younger adults (Cohn, Dustman, & Bradford, 1984; Comalli, Wapner, & Werner, 1962; Eisner, 1972; Hartley, 1993; Houx, Jolles, & Vreeling, 1993; Obler & Albert, 1985; Panek, Rush, & Slade, 1984), indicating that older adults are at least as likely as younger adults to process the distracting words. For the purposes of this study, what is most important is that processing of the irrelevant word appears to be almost automatic, in the sense of being obligatory (cf. Kahneman & Chajczyk, 1983), and this appears to be the case both for older and for younger adults. Reliable identity suppression has been demonstrated in blocks of incongruent Stroop trials (Dalrymple-Alford & Budayr, 1966; Lowe, 1979, 1985; Neill, 1977). The critical trials for identity suppression are those on which the distracting word on one trial becomes the target color on the next trial. Thus, the Stroop procedure provides a situation in which identity suppression has been demonstrated in younger adults and in which older adults should process the distractor at least as extensively as younger adults, if not more extensively. The prediction, then, is that identity suppression in the Stroop procedure should be as large or larger in older adults as in younger adults.

Experiment 1

Method

Participants. Sixteen younger adults and 16 older adults participated in the experiment. Their characteristics are given in Table 1. The younger adults were college students. The older adults were recruited from a local senior citizens' center; they transported themselves to the testing site.

Design. There were five blocks of trials, comprising six experimental conditions, administered in the following, arbitrarily chosen order: *color, blocked congruent, blocked incongruent, word,* and *mixed* (both congruent and incongruent trials). For the color trials, strings of three, four, or five Xs were presented in red, green, or blue on a dark background and the participant was to name the color. For the blocked congruent and incongruent trials, participants saw the words *red, green,* and *blue* presented in red, green, or blue and were to name the color. In the congruent block, the color and the word always agreed; in the incongruent block, they always disagreed. For the word trials, the color names were presented in white on a dark background and the participant was to say the word aloud. For the mixed block, half of the trials were congruent and half were incongruent.

Apparatus and procedure. Stimuli were presented on a high-resolution, 32-cm, Apple color monitor controlled by a Macintosh IIcx computer. Voice responses were collected and input into the computer using hardware and software described by Kieley (1991). Viewing distance was approximately 46 cm, although head position was not constrained. At this distance, each character subtended 36° horizontally and 63° vertically. Three-, four-, and five-character words subtended 1.25°, 1.70°, and 2.15°, respectively. Each block consisted of 20 practice trials followed by 80 experimental trials, except for the mixed block which consisted of 40 practice trials and 160 experimental trials (resulting in 80 congruent and 80 incongruent trials as in the unmixed blocks). Participants were permitted to rest after the practice trials and after every 40 experimental trials. Data from the practice trials were excluded from analysis. On each trial, the stimulus was presented at the center of the display and remained visible until a response was sensed. The participant was instructed to say the word (in the word condition) or to name the color (in all other conditions) as quickly as possible but without making errors. The maximum time allowed for a response was 1,500 ms. The response-to-stimulus interval was 500 ms. The experimental session was tape recorded so that the correctness of responses could be determined later.

Results

In this and subsequent experiments, the alpha level was set at .05. The maximum allowed response time (RT) was 1,500 ms; in addition, RTs shorter than 200 ms were excluded from the analysis. These constraints resulted in loss of 1.0% of the data from younger adults and 1.5% of the data from older adults. Trials on which errors occurred were also excluded from the analysis of RTs. The younger adults committed errors on 1.0%

Table 1
Participant Characteristics

	Experiment 1		Experiment 2	
Characteristic	Younger	Older	Younger	Older
Women/men	11/5	11/5	30/14	24/17
Age				
M	22.1	75.3	20.4	73.3
Range	19–28	67–85	19–32	63–86
Education	15.3	14.1	14.1	16.5
Health	9.4	8.4	7.8	8.7
Acuity	20.0	25.0	22.9	25.1

Note. Education is in mean years completed. Health is a mean self-rating on a 10-point scale, with 10 as excellent. Visual acuity was measured with the Snellen chart at 20 ft (6.10 m); medians are given for Experiment 1; means are given for Experiment 2.

[1] It is important to distinguish among several closely related but distinct concepts. *Identity suppression* is the lengthening of RT on trials that have as a target the color named by the distracting word in the preceding trial relative to the RT in trials in which this does not occur. It is an empirical phenomenon observable in behavior. *Inhibition* is the hypothetical construct presumed to produce identity suppression (but see the discussion of episodic retrieval later). We have used the term, identity suppression, rather than the more general term, *negative priming*, because negative priming subsumes suppression of location as well as suppression of identity and the patterns of age differences in the two phenomena are different (Connelly & Hasher, 1993). We will use the term *Stroop effect* to refer to the difference in RT between incongruent and congruent trials. We will use the term *Stroop interference* to refer to the difference in RT between incongruent and neutral trials. The Stroop effect and Stroop interference are both empirically observable phenomena. They are presumed to be due to a failure to inhibit the distracting word.

Table 2
Reaction Time (in Milliseconds) in Experiment 1

Age group	Color (Xs)	Words	Condition: Congruent blocked	Condition: Incongruent blocked	Condition: Congruent mixed	Condition: Incongruent mixed
Younger adults						
M	557	511	516	736	657	778
SD	66	79	82	107	85	90
Older adults						
M	593	520	525	866	671	853
SD	78	72	53	109	64	81

of the trials; the older adults, on 5.5%. This difference was significant, $t(30) = 2.43$, $p = .03$. This was the only significant effect in the analysis of errors. Most of the errors in the older group were committed by 4 individuals. When those individuals were removed, the error rate dropped to 1.1%. Each of the analyses described below was repeated with these individuals removed. As the pattern of results did not change when they were excluded, the results are reported for the entire sample.

Stroop effect. Analyses were conducted on the mean RT for each participant in each condition. The mean RTs are given in Table 2. An initial analysis showed significant main effects of age group (younger or older), $F(1, 30) = 4.52$, $p = .04$, $MSE = 21{,}950.72$; of condition (color, word, blocked congruent, blocked incongruent, mixed congruent, mixed incongruent), $F(5, 150) = 157.83$, $p < .001$, $MSE = 3{,}691.72$; and of the interaction of age group and condition, $F(5, 150) = 5.05$, $p < .001$, $MSE = 3{,}691.72$. Overall, older adults were 46 ms slower than younger adults. Tests of the simple main effect of age group in each of the conditions showed that older adults were significantly slower than younger adults in the blocked incongruent and mixed incongruent conditions but that the two groups did not differ significantly in any other condition. The Stroop effect—the difference between RTs for incongruent and congruent stimuli—was larger for older adults than for younger adults both in the blocked conditions ($M = 341$ ms for older adults; $M = 221$ ms for younger adults) and in the mixed conditions ($M = 182$ ms for older adults; $M = 121$ ms for younger adults). The Stroop effect in the blocked conditions should be interpreted with caution. In the blocked congruent condition, the color and word are perfectly redundant, so the response could be based on whichever was processed first. In fact, the means in the blocked congruent and word conditions are very similar.

Interference effect. Stroop interference was measured by taking the difference between the mean RT from correct incongruent trials in the mixed condition and the mean RT from correct trials in the color condition for each participant. Interference was higher in older adults ($M = 260$ ms) than in younger adults ($M = 221$ ms), but not reliably so, $F(1, 30) = 1.08$, *ns*, $MSE = 11{,}858.00$.

Identity suppression effect. Following the procedures used by Neill (1977) and Lowe (1979), primary analyses were conducted using the mean correct RTs from the blocked incongruent condition. The blocked incongruent condition was chosen because the color word always interferes, unlike the mixed condition in which it could facilitate on half the trials. Thus, if it is possible to suppress processing of the word, it is strategically sensible to do so. Trials were separated into those in which the color matched the word on the preceding trial ($n = 27$) and those in which the color did not match the preceding word ($n = 53$). Pairs of trials were included in the calculations only if responses were correct on both trials. The mean RTs are given in Table 3. There were significant effects of age group, $F(1, 30) = 4.46$, $p = .04$, $MSE = 36{,}994.42$, and of type of trial (matching or mismatching), $F(1, 30) = 23.99$, $p < .001$, $MSE = 5{,}436.02$. The interaction between age group and trial type was not significant, $F(1, 30) = 0.20$, *ns*, $MSE = 5{,}436.02$. The identity suppression effect—the difference between RTs for nonmatching and matching trials—was virtually the same for older adults ($M = 91$ ms) as for younger adults ($M = 90$ ms). The identity suppression effect could also be calculated from pairs of incongruent trials occurring in the mixed block. An important caveat is that the mixed condition provided many fewer pairs of incongruent trials because only one trial in four, on average, was an incongruent trial following another incongruent trial and only one in three of those had a target color that

Table 3
Reaction Times (in Milliseconds) as a Function of Match or Mismatch Between Distractor on Trial n and Target on Trial n + 1 in Experiments 1 and 2

Age group	Match	Mismatch
Experiment 1		
Younger adults		
M	805	715
SD	105	83
Older adults		
M	907	816
SD	192	174
Experiment 2		
Younger adults		
M	864	829
SD	112	102
Older adults		
M	958	915
SD	145	141

matched the preceding distractor. For the younger adults, there were an average of 7.88 matching trials and 18.88 nonmatching trials with correct responses on both trials of the pair; for the older adults there were an average of 6.13 matching trials and 14.56 nonmatching trials. For the mixed block, the mean identity suppression effect was 76 ms for younger adults and 118 ms for older adults; this difference was not significant, $F(1, 30) = 0.87$, *ns*, $MSE = 15{,}507.33$.

Discussion

These procedures produced a strong Stroop effect, consistent with previous research; an effect that was greater in older adults. The age differences in Stroop interference were not significant, although interference was larger in older adults. Thus, it is likely that older adults were processing the distracting words at least as extensively as younger adults. Most important, the procedures produced very robust identity suppression effects and these effects were virtually equal in younger and older adults. This finding converges with those of Kramer et al. (1994), Sullivan et al. (1995), and Sullivan and Faust (1993), who also found reliable suppression effects that were equivalent in both age groups. It is consistent with the argument that identity suppression will be observed in older adults in conditions with difficult discriminations that make it likely that distractors will be processed. In the Stroop procedure, the distracting word is an integral part of the same stimulus object as the target color and processing of the word appears almost unavoidable (Kahneman & Chajczyk, 1983). One possible explanation, then, is that inhibitory functioning is not impaired in older adults but rather, it may not be elicited under the conditions normally used to demonstrate identity suppression. By this argument, when the situation induces older adults to process the distractors more extensively, they will show suppression resulting from that processing. The implication is that older adults can inhibit distractor identity but normally do not. Thus, the impairment in inhibitory functioning in older adults would not be in the ability to carry out inhibitory processing but in the exercise of that ability.

There is an alternative interpretation that holds that the identity suppression seen in older adults in Experiment 1 may not have been due to inhibition of the distractor. In the incongruent block, one third of the trials was in a color that matched the preceding distractor word; this allowed the measurement of identity suppression. But it is also the case that one third of the trials was in a color that matched the preceding target color. Kane, May, Hasher, Rahhal, and Stoltzfus (in press) proposed that a high proportion of trials with repeated targets will produce identity suppression in older adults (see also May et al., 1995). An alternative to the inhibition theory holds that identity suppression may be the result not of inhibition but rather of episodic retrieval of information from the preceding trial (see Fox, 1995). When a distractor becomes the target on the next trial, the previous stimulus is retrieved, including the target with a "respond" tag and the distractor with a "do not respond" tag. The "do not respond" tag for the distractor from the preceding trial conflicts with the "respond" tag from the current trial, now attached to the target that has the same semantic representation as the preceding distractor, slowing the response. May et al. (1995) maintained that, rather than being alternative theories, inhibition and episodic retrieval are two different mechanisms that produce identity suppression. Which mechanism is active is determined by the situation. Kane et al. (in press, Experiment 3) included a high proportion of repeated-target trials and found significant identity suppression of 8 ms in older adults. An earlier experiment, identical except for the high proportion of repeated targets, produced nonsignificant identity suppression of 3 ms in older adults (Kane et al., 1994). They concluded that a high proportion of repeated targets is one situation that elicits episodic retrieval and that identity suppression produced by episodic retrieval is unaffected by age. They suggested that this can account for the equivalent identity suppression in younger and older adults reported by Sullivan and Faust (1993). It would also apply to the more recent findings of Sullivan et al. (1995). This explanation may also be extended to the findings of Kramer et al. (1994) who used four targets and to the present experiment with three targets.

There are two important points about the episodic retrieval account. First, as Kane et al. (1994) noted, episodic retrieval is logically of no value in a *varied mapping procedure,* that is, one in which the same stimuli serve as targets and distractors on different trials. Over trials, every stimulus will have both "respond" and "do not respond" tags associated with it in the same balance as every other stimulus. The episodic retrieval account makes the most sense if it is assumed that only the most recent preceding trial is retrieved. This assumption is most plausible when trials are presented in clearly demarked pairs, as they are in most identity suppression procedures and, conceivably, only the first trial in a pair (the prime trial) is retrieved. In the present experiment, trials were presented in a continuous sequence rather than in couplets. A second important point is that a memory mechanism is invoked to explain why processing is the same in older and younger adults, whereas age differences in explicit memory are pervasive and well-documented. Nonetheless it is not implausible that the most recent one or two trials are retained in primary memory and that age differences in that memory are relatively slight.

An additional benefit of using the Stroop procedure is that the relationship between Stroop interference and identity suppression can be explored. Because inhibition and episodic retrieval make different predictions about the relationship between interference and identity suppression (see Fox, 1995), it may be possible to determine empirically whether the results from Experiment 1 were consistent with the operation of episodic retrieval or with some other possibility. One possibility is the operation of an inhibitory mechanism that produced both Stroop interference and identity suppression. Effective inhibition of the distracting stimulus on one trial should produce more carry over of inhibition to the next trial. The prediction, then, is that interference and suppression will be negatively correlated. By contrast, episodic retrieval predicts a positive correlation. The more extensively the distracting word was encoded, the greater the interference that it would produce. At the same time, extensive processing of the distracting word would result in a stronger association between the semantic code and the "do not respond" tag. This would produce more difficulty in processing the information on the next trial when the target color elicited that same semantic code but with the "respond" tag now attached. The difficulty would be manifest as the slowing charac-

Table 4
Correlations Between Stroop Effects and Identity Suppression Effects

Age group	Stroop effect: Incongruent–congruent	Interference effects: Incongruent–neutral	Interference effects: Incongruent–color
Experiment 1			
Younger adults	.28 (.28)	—	.46 (.46)
Older adults	.26 (.37)	—	.52* (.59)
Overall	.20 (.30)	—	.48** (.54)
Experiment 2			
Younger adults	.00 (.00)	−.17 (−.09)	−.09 (−.02)
Older adults	−.08 (−.08)	−.17 (−.08)	−.08 (−.17)
Overall	.00 (.00)	−.17 (−.06)	−.06 (−.06)

Note. Dashes indicate that data were not collected in Experiment 1. Values in parentheses are before removal of influential, leveraging cases. * $p < .05$. ** $p < .01$.

teristic of identity suppression. Thus, greater interference would be associated with greater suppression. A third possibility is that both interference and suppression may be the result of inhibitory mechanisms, but the mechanisms may be independent. Interference may be handled by mechanisms for concurrent selection, whereas suppression may be an effect of the operation of mechanisms acting after selection, for example, to prevent recently rejected information from gaining access to effectors (May et al., 1995). This predicts no correlation between interference and suppression.

Correlations between interference and identity suppression were calculated from the data of Experiment 1. The magnitude of the Stroop interference effect (RT on mixed incongruent trials less RT on color only trials) and the identity suppression effect (RT on match trials less RT on nonmatch trials) were calculated for each person. The correlations of the interference effect (and also the Stroop effect—RT on incongruent trials less RT on congruent trials) with the suppression effect are given in Table 4. A preliminary analysis was conducted to identify cases that may have leveraged the correlations. Cases with extreme values of Cook's Distance were removed. (An extreme value was defined as more than 3 times the interquartile range above the median.) The correlations before removal of extreme values are shown in parentheses in Table 4. The correlations were uniformly positive; they were significant for older adults and for the total sample and approached significance for the younger adults. The positive correlations are consistent with the operation of episodic retrieval; they are not consistent with the operation of a common inhibitory mechanism that produces both interference on one trial and identity suppression on the next.[2]

Experiment 1 had a relatively high proportion of repeated target colors and evidenced identity suppression in older adults. May et al. (1995) and Kane et al. (in press) asserted that a high proportion of trials with repeated targets would elicit episodic retrieval and, therefore, would produce identity suppression in older adults. The positive correlations between Stroop interference and identity suppression are consistent with episodic retrieval in Experiment 1. The converse of the assertion by May et al. and Kane et al. is that eliminating repeated-target trials would reduce or eliminate episodic retrieval and, as a result, reduce or eliminate identity suppression in older adults. Experiment 2 was conducted to test this latter prediction. In the incongruent trials from which identity suppression was measured, there were no repeated targets. Either the distractor word on one trial became the target color on the next trial or there was no overlap between the trials. Thus, there were no trials on which the target color from the preceding trial was repeated. One additional change was implemented. In Experiment 1, there were no neutral trials in the mixed block, that is, trials in which color-unrelated words or letter strings (e.g., XXXX) were presented in color. Neutral trials would allow a second measure of Stroop interference using RTs from incongruent and neutral trials presented under exactly the same conditions. A measure based on mixed blocks would eliminate the possibility that individuals adopt a strategy tailored to a particular type of stimulus.

Experiment 2

Method

The procedure was presented to the participants as a single task. The instruction for the task was to name only the color that they saw, ignoring letters or words that formed the stimulus. The first block of 48 trials consisted of color-unrelated words. This was followed by three blocks: a block of 36 trials that mixed congruent, incongruent, and neutral stimuli; a block of 60 incongruent trials; and a block of 36 mixed trials. The block of incongruent trials used to assess identity suppression was placed after the mixed block to reduce the chance that participants would notice the nature of the block. On neutral trials, the stimuli were strings of Xs. In addition, because some younger adults had reported that they squinted or viewed the stimuli peripherally to avoid reading the words, the stimuli were enlarged.

Participants. Forty-five younger adults and 45 older adults from the same populations as Experiment 1 participated in the experiment. Because of problems with the voice-sensing apparatus, data from 1 younger adult and 4 older adults could not be used, resulting in final samples of 44 younger adults and 41 older adults. Their characteristics are given in Table 1.

Displays. The colors used were red, blue, green, and yellow. For the initial block of color-unrelated words, the words used were *rug, boat, glove,* and *yeoman.* In the mixed blocks, one third of the stimuli had congruent color and word, one third had incongruent color and word, and one third was neutral. Neutral stimuli consisted of 3, 4, 5, or 6 Xs. The ordering of stimuli was random. On half of the trials in the incongruent block, the target color matched the distracting word of the preceding trial. On the other half, both color and word were different from either the color or distractor on the preceding trial.

Procedure. Stimuli were presented on an SVGA 33-cm monitor

[2] It has been argued that an inhibitory mechanism could also produce a positive correlation (Fox, 1995). The argument is that distractor inhibition is invoked only when distractor interference is very high. This predicts that individuals who experience a high amount of interference will be those who demonstrate high levels of suppression. The argument is implausible. The inhibition is invoked presumably to handle interference from the concurrent distractor. Yet, the inhibition could not aid concurrent selection substantially; if it did, it would reduce interference and produce a negative relationship.

driven by an Intel 486-based computer. Stimulus presentation and voice response collection were controlled by the Micro Experiment Laboratory (Version 1.0) software and response box (Schneider, 1990). As in Experiment 1, viewing distance was approximately 46 cm, although head position was not constrained. Stimuli were presented against a dark background. A white rectangle, subtending 2.48° vertically and 10.83° horizontally, appeared first. Next, either a 3-to-6 character word or a string of 3-to-6 Xs was presented within the rectangle; these strings subtended 1.61° vertically and 4.60° to 9.38° horizontally. Each trial began with a presentation of the rectangle for 500 ms to establish fixation. Next, the letter string appeared for 1,500 ms or until a voice response was sensed. The participant was instructed to name the color as quickly as possible but without making errors, ignoring the letters or words that appeared. The response-to-stimulus interval was 1,000 ms. There was a rest break after each block. The experimental session was tape recorded so that the correctness of responses could be determined later.

Results

Again, responses shorter than 200 ms were excluded from the analysis as were trials on which a response was not given or was not detected and responses longer than 1,500 ms were not permitted. These constraints resulted in a loss of 8.7% of the data for younger adults and 8.3% for older adults. Trials in which errors occurred were also excluded from analysis. There were no significant effects in the analysis of errors. Across all conditions, errors occurred in 3.0% of the trials for both younger and older adults.

Stroop effect. Analysis of variance on the RTs in the mixed blocks showed significant main effects of age group, $F(1, 83) = 9.37$, $p = .003$, $MSE = 26{,}238.55$, and of congruity (congruent, neutral, and incongruent), $F(2, 166) = 151.19$, $p < .001$, $MSE = 3{,}282.80$. The interaction of age group and congruity was also significant, $F(2, 166) = 8.32$, $p < .001$, $MSE = 3{,}282.80$. Mean RTs are given in Table 5. Tests of the simple main effect of age group for each congruity condition showed that younger and older adults differed significantly on incongruent and neutral trials but not on congruent trials. Compared with neutral stimuli, congruent words produced a small cost for younger adults and a small benefit for older adults; neither was significantly different from zero. The *Stroop effect,* defined as the difference between RTs to incongruent and congruent stimuli, was larger for older ($M = 171$ ms) than for younger adults ($M = 99$ ms).

Interference effects. Stroop interference was measured in two ways. The first measure was the difference between the mean RT from correct incongruent trials in the mixed blocks and the mean RT from correct neutral trials in the same blocks. Interference was higher in older adults ($M = 150$ ms) than in younger adults ($M = 110$ ms), $F(1, 83) = 4.44$, $p = .04$, $MSE = 7{,}640.56$. The other measure of interference was similar to that used in Experiment 1: Interference was measured by taking the difference between the mean RT from correct incongruent trials in the mixed blocks and the mean RT from correct trials in the color-unrelated words block. Interference was equivalent in older adults ($M = 146$ ms) and in younger adults ($M = 152$ ms), $F(1, 83) = 0.07$, *ns*, $MSE = 8{,}589.62$.

Identity suppression effect. Analyses were conducted using the mean correct RTs from the incongruent block.[3] Trials were separated into those in which the color matched the word on the preceding trial and those in which there was no relation between successive trials. The mean RTs are shown in Table 3. There were significant effects of age group, $F(1, 83) = 11.42$, $p = .001$, $MSE = 30{,}259.75$, and of type of trial (matching or unrelated), $F(1, 83) = 48.60$, $p < .001$, $MSE = 1{,}344.27$. The interaction between age group and trial type was not significant, $F(1, 83) = .51$, *ns*, $MSE = 1{,}344.27$. The identity suppression effect did not differ for older adults ($M = 43$ ms) and for younger adults ($M = 35$ ms), as indicated by the nonsignificant interaction.

Individual differences. The magnitude of both measures of the Stroop interference effect and the identity suppression effect were calculated for each person. The correlations of the interference effects (calculated in the two different ways) as well as the Stroop effect with the suppression effect are given in Table 4. Once again, correlations were obtained with leveraging cases removed; the original correlations are shown in parentheses in Table 4. The pattern of correlations is different from the positive correlations found in Experiment 1. All the correlations between interference and suppression are negative, although none of them is significantly different from zero. Each correlation is, however, significantly lower than the corresponding correlation coefficient in Experiment 1 for cases in which it was possible to make a comparison. Because correlations between two measures are theoretically bounded by the reliability of the measures, the low correlations could be a result of low reliability. Consistent with this interpretation, split-half reliabilities estimated by the Spearman–Brown formula were .80 for Stroop interference but only .32 for identity suppression. To obtain these reliabilities, measures of the effects from the first and fourth quarters of the trials, combined, were correlated with measures from the second and third quarters.

Table 5
Reaction Times (in Milliseconds) for Stroop Effects in Experiment 2

	Condition for test words			
Age group	Color-unrelated	Congruent	Neutral (Xs)	Incongruent
Younger adults				
M	670	722	712	822
SD	97	95	97	108
Older adults				
M	775	750	771	920
SD	86	115	99	112

Discussion

As in Experiment 1, the Stroop effect was reliably larger in older adults than in younger adults. Stroop interference was

[3] In Experiment 2, no attempt was made to calculate the identity suppression effect from the mixed trials. There were 72 mixed trials, one third of which was incongruent. Thus, one trial in nine would be an incongruent trial following another incongruent trial. With four colors, on average, one such trial in four would have a target color that matched the preceding distractor. On average, then, we would expect only two matching trials and six nonmatching trials. This would produce highly unreliable estimates for the means for matching and nonmatching trials and extremely unreliable estimates for the identity suppression effect.

greater in older adults when using neutral trials as the comparison; the age groups were equivalent when RIs from the color-unrelated words were used as the comparison. Although age equivalence of Stroop interference is a surprising finding, it does not compromise the results for identity suppression because it still indicates that older adults processed the distracting words at least as extensively as younger adults. In spite of the removal of repeated target trials, the identity suppression effect was reliable and did not differ in the two age groups; in fact, it was slightly greater in older adults. The correlations between interference and identity suppression were small but negative, unlike the positive correlations found in Experiment 1. The change in the pattern of correlations is consistent with the interpretation that target repetition did produce episodic retrieval in Experiment 1 and that eliminating repeated targets in Experiment 2 suppressed episodic retrieval. Preventing target repetitions did not, however, reduce or eliminate identity suppression in older adults.

The correlational results are ambiguous. Although the results were not consistent with episodic retrieval, they were also inconsistent with the model that motivated these experiments. One possibility is that there is a small but real negative correlation between interference and identity suppression. It was argued that processing of the distracting word in the Stroop procedure was obligatory and, so, older adults would be induced to process the distractor. Presumably, they would then use inhibitory mechanisms to suppress processing of the distractor and that suppression would persist when the distractor reappeared as the target on the subsequent trial. This model predicted a negative correlation between Stroop interference and identity suppression. Effective suppression of processing of the distracting word should lead to lower Stroop interference and to greater identity suppression. The reliability of the identity suppression effect was low and this may have attenuated the correlation. If the correlation is real and negative, an inhibitory mechanism could account for the results of Experiment 2. A second alternative, given that the correlations did not differ significantly from zero, is that the true state of affairs may have no relation between interference and identity suppression. This would imply that, at least in this procedure, interference and identity suppression result from independent mechanisms. Yet, a third interpretation is possible, although the explanation lacks parsimony: The absence of a correlation between interference and identity suppression may be the result of a mixture of some individuals in whom inhibitory mechanisms are elicited and others in whom episodic retrieval is elicited.

General Discussion

The results of these experiments are clear but, at the same time, add to the confusion about inhibition in older adults. The results are clear in showing strong and reliable identity suppression effects, effects that were equivalent in younger and older adults. This finding is consistent with results reported by Sullivan and Faust (1993), Sullivan et al. (1995), and Kramer et al. (1994) even though the methods used by those authors and in the present study are all different from one another. The results are inconsistent with earlier results that had led Fox (1995) and May et al. (1995) to conclude that identity suppression does not occur in older adults. The confusion comes because identity suppression has been proposed as the "best available index of inhibitory attentional processing" (Kane et al., in press). Earlier failures to find identity suppression in older adults were taken as evidence for an impairment of inhibitory functioning in old age (Fox, 1995; May et al., 1995). Results showing equivalent identity suppresion in older and younger adults are clearly problematic for this position. The explanation that was offered was that identity suppression could result from other than inhibitory mechanisms, specifically retrieval of prior events (Kane et al., in press; May et al., 1995). This, of course, means that the presence of identity suppression can no longer be taken as an unequivocal index of inhibitory processing. The results of the study showed that identity suppression occurred in older adults in a situation that appeared to involve episodic retrieval, but they also demonstrated suppression in older adults in a situation that apparently did not elicit episodic retrieval and may or may not have elicited inhibitory processing. Any claim that lower identity suppression in older than in younger adults indicates an inhibitory impairment will require independent evidence that the particular procedure used elicited inhibitory processing.

One concern is that the identity suppression effects in Experiment 1 (M = 90 ms) were much larger than those in Experiment 2 (M = 39 ms). (The effects in both experiments were larger than those in other studies that have found age-equivalence in identity suppression, but that is likely the result of procedural differences.) This may have been the result of the blocking of conditions in Experiment 1. To determine whether the results were general, we conducted an additional experiment using procedures comparable to those in Experiment 2 with the principal exception that only two colors were used, so that target repetitions occurred in half of the trials. Thus, this experiment had the target repetitions of Experiment 1 but did not have the obvious blocks of trial types. The other difference was that manual responses were used because of the insensitivity of the voice-sensing apparatus used in Experiment 2. There were 24 older and 24 younger adults. The mean identity suppression effect was 41 ms for the older adults and 32 ms for the younger adults. As in Experiment 1, correlations between interference and identity suppression were positive: For interference measured as the difference between incongruent and neutral trials, r = .20; for interference measured as the difference between incongruent trials and the block of color-unrelated words, r = .24. Thus, the results replicated those of Experiment 1, although both the identity suppression effects and the correlations were attenuated.

As the findings reviewed at the outset show, an age-related difference in identity suppression is a reliable finding. Combining these results with those of Kramer et al. (1994), Sullivan and Faust (1993), and Sullivan et al. (1995), so, however, is an age-related equivalence. There are certainly multiple determinants of identity suppression. One determinant may be a relatively general inhibitory mechanism, general enough to operate both for concurrent selection on one trial and subsequent selection on the next. Another may be an inhibitory mechanism that operates after selection on the current trial has occurred and, so, does not affect that trial but does affect selection on the subsequent trial. Yet another determinant may be a retrieval mechanism that is not inhibitory. In the absence of a touchstone

for the determinant(s) of identity suppression in a particular procedure, interpretation of the pattern of age differences and similarities will remain ambiguous.

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