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Automatic and Attentional Priming in Young and Older Adults: Reevaluation of the Two-Process Model

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Three experiments addressed the distinction between automatic and attentional mechanisms underlying semantic priming effects by factorially crossing prime–target relatedness, expectancy, and SOA in a task (pronunciation) that minimized postlexical checking processes. Also, possible age-related (young vs. older adults) differences in the automatic and attentional mechanisms were addressed. Across all experiments there was evidence of a Relatedness × Expectancy × SOA interaction, which is inconsistent with the notion of independent automatic and attentional mechanisms in semantic priming and the notion of a self-encapsulated modular lexicon. The results also indicated age-related differences in the build-up of the expectancy effect across SOAs when the prime was visually available for only 200 ms, independently of the prime–target SOA (Experiments 1 and 3), but not when the prime was visually available throughout the SOA (Experiment 2).

Semantic priming effects have been one of the most widely studied phenomena in cognitive psychology (see Neely, 1991, for a review). In general, such effects refer to the simple finding that subjects respond faster to a word (e.g., *cat*) when it follows a related word (e.g., *dog*) than when it follows an unrelated word (e.g., *can*). The interest in semantic priming effects has been nourished by the utility of the priming paradigm to uncover the structural/processing characteristics of the word-recognition system along with basic cognitive mechanisms such as automatic spreading activation and attentional direction within semantic memory.

Our research had two major goals. The first goal was to provide further information concerning the relation among the variables prime–target relatedness, prime–target expectancy, and prime–target stimulus onset asynchrony (SOA). As discussed later, these manipulations have been at the heart of the distinction between priming effects that reflect automatic spreading activation and priming effects that reflect a limited-capacity attentional mechanism. Moreover, the distinction between automatic and attentional mechanisms underlying semantic priming effects has been central to theoretical arguments concerning the architecture of the language-processing system: specifically, the notion of a self-encapsulated modular lexicon (see Fodor, 1983).

Our second goal was to provide further information concerning age-related changes in the characteristics of these two mechanisms. As described later, there has been considerable effort in the literature on aging to isolate age-related changes in specific cognitive mechanisms through the use of the semantic priming task.

The Two-Process Model of Priming

In a classic study, Neely (1977) developed a paradigm to distinguish between automatic and attentional mechanisms underlying semantic priming effects. Neely's work was based on Posner and Snyder's (1975) distinction between automatic and attentional processes. According to Posner and Snyder, automatic processes are fast acting, are independent of the subject's conscious expectancies, and produce only facilitation, in comparison to a neutral baseline (e.g., xxxx). Attentional processes are rather slow to engage, are dependent on the subject's conscious expectancies, and produce both facilitation and inhibition, in comparison to a neutral baseline. Neely used Posner and Snyder's framework to distinguish between the impacts of automatic and attentional mechanisms underlying semantic priming effects. He manipulated (a) the pre-existing relation between primes and targets (e.g., *flower–daisy* vs. *flower–tuna*), (b) the subjects' expectancies concerning where to direct attention (e.g., when presented the prime *metal,* the subjects were instructed to think of either *types of metals* or *types of trees*), and (c) the time available to process the prime information before the target was presented (the prime–target SOA). The results of Neely's study supported Posner and Snyder's framework; that is, the automatic influence of the pre-existing relation (reflected by the relatedness effect) developed quite fast and had primarily a facilitatory impact in the short SOAs, whereas the attentional influence (reflected by the expectancy effect) was rather slow to develop and had both a facilitatory and an inhibitory impact in the long SOAs. Similar distinctions between the automatic and attentional mechanisms in semantic priming

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were reported by Burke, White, and Diaz (1987) and Favreau and Segalowitz (1983).

Although Neely's (1977) results clearly supported Posner and Snyder's (1975) framework, two aspects of this work require some discussion. First, one might question whether the neutral prime (a row of *x*s) that Neely used provided a valid baseline for measuring costs and benefits (see Jonides & Mack, 1984). De Groot, Thomassen, and Hudson (1982) found that response latencies in the lexical decision task (LDT) were inhibited by the use of a row of *x*s in comparison with the word *blank* (also see Antos, 1979). Thus the use of *xxxxx* as a neutral prime may produce an overestimate of facilitation and an underestimate of inhibition. The important point here is simply that the choice of a given neutral baseline modulates the extent to which one observes costs and benefits in the semantic priming task. Fortunately, the importance of Neely's study and of its relevance to Posner and Snyder's model does not rest on measuring costs and benefits. Specifically, one should find that the impact of the automatic component (as reflected by the relatedness effects) should decrease across SOAs, independently of the subject's expectancies, whereas the impact of the attentional component (as reflected by expectancy effects) should increase across SOAs, independently of the prime–target relatedness (see Neely, 1977, Figure 1).

The second noteworthy aspect of the work in this area is that in all three published studies in which prime–target relatedness, expectancy, and SOA were factorially crossed (Burke et al., 1987; Favreau & Segalowitz, 1983; Neely, 1977), the investigators relied on lexical decision performance as the dependent measure. This is important because evidence indicates that priming effects in the LDT not only reflect the automatic spreading-activation mechanism and the attentional mechanism but also reflect a postaccess backward search from the target to the prime for a semantic relation (e.g., Balota & Chumbley, 1984; Balota & Lorch, 1986; de Groot, 1984; Forster, 1979, 1981; Lorch, Balota, & Stamm, 1986; Lupker, 1984; Neely, 1991; Neely, Keefe, & Ross, 1989; Seidenberg, Waters, Sanders, & Langer, 1984; Stanovich & West, 1983). Very simply, there is a confounding in the LDT between the type of response that the subject makes and the manipulation. Words can be related to the primes, but nonwords are always unrelated to the primes. Therefore, subjects might use the detection of a prime–target relation to bias their "word" responses, thereby facilitating responses to related prime–target pairs in comparison with unrelated prime–target pairs. In order to avoid this difficulty with the LDT, the aforementioned researchers in this area have argued that the pronunciation task may be a better reflection of the directional (forward) impact from the prime to the target because this task does not involve a binary decision that is inherently tied to the relatedness manipulation.

In this light, one of our primary goals was to factorially cross prime–target relatedness, expectancy, and SOA to address the two-process theory in a situation that minimizes the contaminating processes that result from the binary decisions inherent in the LDT. In pursuit of this goal, we used the pronunciation task. It is possible that some or all of the effect attributed to either automatic spreading activation or attentional expectancies may have actually been caused by postaccess processing in the previous lexical decision studies. Hence to fully address the two-process theory of semantic priming, we factorially crossed prime–target relatedness, expectancy, and SOA in a situation (pronunciation) that eliminated the postaccess processes that contribute to performance in the LDT.

According to the two-process theory, noted earlier, the predictions are quite straightforward. Specifically, the influence of the automatic component (as reflected by the preexisting prime–target relatedness effect) should decrease across SOAs, whereas the impact of the attentional component (as reflected by the expectancy effect) should increase across SOAs. In addition, there should be no evidence of a three-way interaction among relatedness, expectancy, and SOA. The absence (or presence) of this three-way interaction is especially important for the separability of the two mechanisms underlying priming effects and of particular interest in our research.

As noted earlier, our second major goal was to address age-related changes in the spreading activation and attentional mechanisms underlying semantic priming effects. We will now briefly discuss this literature.

Age-Related Changes in Priming Effects

Older adults perform more poorly than do younger adults on a wide variety of memory tasks. Some researchers have suggested that this age-related memory deficit is caused by an impairment in semantic processing (e.g., Cohen, 1979; Craik & Byrd, 1982; Craik & Simon, 1980; Eysenck, 1974; Rabinowitz & Ackerman, 1982; Rabinowitz, Craik, & Ackerman, 1982; Simon, 1979).

Of course, documenting a semantic processing deficit is not the same as understanding its underlying mechanism or mechanisms. In order to identify these mechanisms, researchers have used the semantic priming paradigm. However, the results from the priming experiments have not provided much evidence concerning the locus of an age-related semantic processing deficit. Specifically, considerable evidence indicates that there are no age-related changes in semantic priming effects (e.g., Balota & Duchek, 1988, 1989; Bowles & Poon, 1985; Burke et al., 1987; Cerella & Fozard, 1984; Chiarello, Church, & Hoyer, 1985; Howard, 1983; Howard, McAndrews, & Lasaga, 1981).

Although overall priming effects have been relatively constant across age groups, it is also important to attempt to isolate the underlying mechanisms that may produce the semantic priming effects (Bowles & Poon, 1985; Chiarello et al., 1985). It is obvious that an increased reliance on one mechanism that produces priming effects could be compensated for by a decreased reliance on a second or a third mechanism. Thus our second goal was to isolate age-related changes in either the automatic or the attentional mechanisms that may underlie semantic priming effects. Before describing in detail our experiments, we briefly discuss a study that is particularly relevant to our work.

In their study, Burke et al. (1987) took a major step toward understanding the underlying nature of priming effects in younger and older adults. This study was based in part on the research by Neely (1977), and it was an attempt to distinguish between the automatic and the attentional mechanisms underlying semantic priming effects. Thus Burke et al. factorially crossed prime–target relatedness, expectancy, and SOA. Like Neely (1977), Burke et al. found that with the short prime–target SOA, performance was primarily modulated by the preexisting semantic relation between the prime and the target, independently of the subjects' expectancies. On the other hand, with the long SOA, Burke et al. found that performance was primarily modulated by subjects' expectancies, independently of the pre-existing prime–target relation. Thus Burke et al. found that relatedness interacted with SOA and that expectancy interacted with SOA, but there was no three-way interaction among relatedness, expectancy, and SOA, precisely as predicted by the two-process model. Of more importance for this discussion, Burke et al. found that age was additive with this pattern of data. Therefore, they concluded that neither the automatic nor the attentional component of semantic priming changed as a function of age.

Our experiments provide further evidence regarding age-related differences in the automatic and attentional components underlying semantic priming effects. Our research differed from Burke et al.'s (1987) study in the following three ways. First, our experiments involved three SOAs instead of two SOAs. The importance of the third SOA was to determine whether there was a change in the *rate* of these processes across time. With only two SOAs, one cannot make strong statements about the underlying build-up or decay of the automatic and attentional components. The inclusion of a third SOA was quite important in our results. Second, we attempted to tease apart a prime-based expectancy from a probability-based expectancy. Both in our experiments and in Burke et al.'s study, exemplars from expected categories were more likely to occur within a block of trials than were exemplars from unexpected categories; therefore, it was important to obtain an estimate of the influence of expectancy generated by probability differences across expected and unexpected categories from the influence of expectancy generated by the identity of the prime. In order to obtain such an estimate, we included prime trials that did not specify which category to expect (the prime was the word *READY*). Because of this lack of specification, any impact of expectancy should reflect the fact that exemplars from the expected categories have a higher probability of occurrence in a given block of trials than do exemplars from unexpected categories. The difference between the category prime trials and the *READY*-prime trials can be used as an estimate of the prime-induced expectancy.

The third and most important difference is that our study included a pronunciation task instead of Burke et al.'s (1987) LDT. This modification is important because, as noted earlier, there is now clear evidence that priming effects in the LDT reflect the contribution of a third factor that involves a postaccess search for a relation between the primes and targets. Moreover, de Groot (1985) argued that high-probability prime–target pairs, such as in Burke et al.'s expected conditions and in our experiments, are more likely to produce effects of backward checking from the target to the prime in the LDT (see, however, Neely et al., 1989).

Experiment 1

The major conditions of Experiment 1 are displayed in Table 1. The relatedness manipulation should primarily reflect the automatic component and therefore influence performance at the short SOAs, whereas the expectancy manipulation should primarily reflect the attentional mechanism and therefore influence performance at the long SOAs. The design of Experiment 1 was a 2 (young vs. old) × 2 (expected vs. unexpected prime–target pair) × 2 (related vs. unrelated prime–target pair) × 3 (250-ms, 1,000-ms, and 1,750-ms SOA) mixed-factor design. The major dependent variables were voice-onset latency and percentage correct.

Method

Subjects

Forty-eight young adults (15 men and 33 women) and 48 older adults (20 men and 28 women) participated in Experiment 1. The mean age for the young adults was 25 years, and their ages ranged between 18 and 37 years; the mean age of the older adults was 71 years, and their ages ranged between 65 and 81 years. The older adults had slightly less formal education (M = 14.2 years) than did the younger adults (M = 15.0 years); however, they scored slightly higher (30.4) on the vocabulary subsection of the Wechsler Adult Intelligence Scale (WAIS) (Items 15–40) than the younger adults (M = 28.5). The only difference to reach significance was age. No subject participated in more than one of these experiments.

Apparatus

Stimulus presentation and data collection were controlled by an Apple IIe microcomputer that was equipped with a Mountain Hardware clock that provided accuracy to the nearest millisecond. A software routine ensured that stimulus presentation was synchronized to the raster scanner pulse. A Gerbrands G1341T electronic voice key was integrated with the computer to detect voice onsets.

Materials

A total of 28 categories were selected from Battig and Montague's (1969) norms. From each of the 24 test categories, the 19 most dominant responses were used as test stimuli. Whenever an exemplar that appeared in one category was already selected for a different

Table 1
Example Set of Critical Conditions

Relatedness	Expected	Unexpected
Related	*FLOWER–daisy*	*METAL–silver*
Unrelated	*METAL–elm*	*FLOWER–tuna*

Note. In this example, the subjects were given instructions to think of "types of flowers" when presented the category name *FLOWER*, but when presented the category name *METAL*, they were to think of "types of trees."

category, the next dominant response within the first category was used. From each of the four categories that were used for the practice block, only 12 items were selected. Thus the stimulus materials consisted of 28 category names and a total of 504 category exemplars.

The four major priming conditions are displayed in Table 1. Within a test block, subjects underwent a total of 54 prime–target trials. As shown in Table 1, with the exception of the noncategory prime trials, in which the word *READY* was the prime, subjects received one of two different category names as primes and words from one of four categories as targets within a block of trials. The first two trials within a block were always buffer trials that included one prime–target pair from the expected-related condition and one prime–target pair from the expected-unrelated condition. The remaining 52 trials consisted of 24 critical trials and 28 additional buffer trials. The 24 critical trials included 4 trials from each of the four critical conditions displayed in Table 1, along with 2 noncategory prime trials (*READY*) from each of the two expected categories and 2 noncategory prime trials from each of the two unexpected categories.

The 28 buffer trials within each test block were included in order to further induce the category expectancies. Of these trials, 12 were from the expected-related condition, 12 were from the expected-unrelated condition, and 4 were primed by the noncategory prime (*READY*), with two targets from the expected-related category and two targets from the expected-unrelated category.

Target items were counterbalanced across prime conditions and SOAs in the following fashion. Within each group of 3 subjects, a given prime–target pair occurred once with each of the three SOAs. Across groups of 3 subjects, a given target word appeared once in each of the four critical prime-target conditions. Thus in order to counterbalance a given target item completely across both SOA and prime–target condition, data from 12 subjects were necessary (i.e., 3 SOAs × 4 prime–target conditions). Of course, when target items switched from expected to unexpected conditions and vice versa, a new set of buffer items that represented the "expected" categories were included. With this counterbalancing procedure, each subject received eight trials in each of the critical conditions displayed in Table 1, along with eight trials in the noncategory prime conditions, at each of the three SOA conditions. No target word was repeated within an experimental session. Subjects participated in a total of six test blocks.

Procedure

Subjects were told that on each trial they would receive two words. The first word was primarily a cue to generate an expectancy concerning the second word, which they were to pronounce aloud as quickly and as accurately as possible. Subjects were told that within a block of trials, they should expect items from two different categories. For one of the expected categories, subjects would receive items from the same category designated by the prime item. For example, if the category name *TOYS* was presented, subjects were instructed to expect items from the category *TOYS* (e.g., *skates, doll, ball*). For the second expected category, subjects would receive items from a category that was different from the category designated by the prime item. On these trials, subjects were instructed to switch their attention to the new category. For example, if they received the category name *STATES*, then they should begin thinking of types of metals (e.g., *tin, copper, silver*). Finally, subjects were told that on some trials the word *READY* would serve as the first word. No explicit instructions were given for the noncategory (*READY*) prime trials.

After subjects indicated that they understood the verbal instructions, they pressed the "1" button on the computer keyboard to begin the experiment. After pressing this button, the following instructions about the expectancy manipulation for the practice trials were displayed on the computer screen:

> For the following block of trials, when you receive the category name [related-expected category name], it is crucial that you think of items from the category [related-expected category name]. However, when you receive the category name [unrelated-expected category name], it is crucial that you switch your attention and think of items from the different category [unrelated-expected category name]. REMEMBER this is important. Type the digit 1 when you are sure you have the above category instructions completely understood.

The experimenter remained with the subject for the first 24 practice trials to ensure that the subject fully understood the expectancy instructions. Also, during this period, subjects were instructed to monitor whether correct pronunciations triggered the computer. Specifically, they were told that after they pronounced the target aloud, they would receive a message to press either the "1" key or the "0" key. If they believed that any sound besides their correct pronunciation triggered the computer (e.g., an incorrect pronunciation, a cough, or some other extraneous sound), they were to press the "1" key; otherwise, they were to press the "0" key. Subjects were also shown how the voice key was sensitive to extraneous sounds through a light-emitting diode on the voice key.

The following sequence occurred on each prime–target trial: (a) a row of three asterisks separated by blank spaces in the center of the screen for 300 ms; (b) a blank screen for 300 ms; (c) a warning tone for 150 ms; (d) a blank screen for 300 ms; (e) the uppercase prime item in the center of the screen for 200 ms; (f) depending on the prime–target SOA for that trial, a blank screen for 50 ms, 800 ms, or 1,550 ms; (g) the target item presented at the same location as the earlier presented prime item; (h) the subject's pronunciation (or extraneous sound) triggering the voice key; (i) erasing of the target item from the screen; (j) the message "TYPE IN A '0' IF CORRECT OR A '1' IF THERE WAS ANY PROBLEM" presented in the center of the screen; (k) the subject's keypress, which initiated a 2.4-s intertrial interval.

Subjects were seated approximately 60 cm from the computer screen in a sound-deadened testing room. They were told that they could take a break between blocks at any time throughout the experiment. Testing sessions lasted approximately 75–90 min.

Results

Each subject's overall mean response latency and standard deviation were first calculated. Any response that exceeded either 2.5 standard deviations above or below the mean or 500 ms above or below the mean was treated as an outlier. (Outliers accounted for fewer than 2% of all the observations.) From the remaining correct responses, as indicated by the subject's pressing "0" after a given trial (see *Method* section), a mean response latency was calculated for each subject per cell. Also, a mean percentage correct based on the number of trials that were neither outliers nor "incorrect" was calculated for each cell. This procedure was used for all three experiments.

Critical Targets

Onset latencies. In Table 2 we present the mean onset latencies and percentages correct for the critical targets as a

Table 2
Mean Onset Latency (ON) and Percentage Correct (%C) for the Target Words as a Function of Age, Stimulus Onset Asynchrony, Relatedness, and Expectancy: Experiment 1

	Related				Unrelated			
	Expected		Unexpected		Expected		Unexpected	
Time	ON	%C	ON	%C	ON	%C	ON	%C
Younger adults								
250 ms	519	96	534	95	532	96	532	96
1,000 ms	470	97	496	96	482	98	493	94
1,750 ms	471	98	494	94	469	99	496	94
Older adults								
250 ms	660	97	672	94	676	96	674	93
1,000 ms	594	98	611	95	595	97	629	94
1,750 ms	614	97	616	95	612	98	622	94

function of age, SOA, relatedness, and expectancy. There are three points to note in this table. First, older adults had longer onset latencies than did younger adults. Second, there was a considerable drop in response latency between the 250-ms and the 1,000-ms SOAs. Third, this latter pattern was stronger for the older adults than for the younger adults.

In Table 3 we present the mean relatedness (unrelated condition minus related condition) and mean expectancy (unexpected condition minus expected condition) effects as a function of age and SOA. As noted, the relatedness effects should reflect primarily the automatic component, whereas the expectancy effects should reflect primarily the attentional component. There are two important aspects of these data. First, as indicated in the top half of this table, there was a relatively small overall impact of relatedness that appeared to decrease across the SOAs for the expected conditions but not for the unexpected conditions. Second, as indicated in the bottom half of the table, for the younger adults, it appears that the expectancy effect overall increased across SOAs. However, for the older adults, the impact of expectancy actually appeared to increase between the 250-ms and the 1,000-ms SOAs but then decreases during the 1,750-ms SOA.

These observations were supported by a 2 × 2 × 2 × 3 (Age × Relatedness × Expectancy × SOA) mixed-factor analysis of variance (ANOVA). This analysis yielded main effects of age, $F(1, 94) = 55.31$, $MS_e = 91{,}148$; of SOA, $F(2, 188) = 167.25$, $MS_e = 2078$; of relatedness, $F(1, 94) = 55.31$, $MS_e = 968$; and of expectancy, $F(1, 94) = 31.78$, $MS_e = 1{,}881$. (Unless otherwise specified, for all effects referred to as significant, $p < .05$.) This analysis also yielded a significant interaction between age and SOA, $F(2, 188) = 4.43$, $MS_e = 2{,}078$, indicating that the difference between the 250-ms SOA and the 1,000-ms SOA was larger for the older adults (64 ms) than for the younger adults (44 ms). The SOA × Expectancy interaction also reached significance, $F(2, 188) = 5.15$, $MS_e = 1{,}107$, indicating that the expectancy effects were overall larger for the 1,000-ms SOA (22 ms) and the 1,750-ms SOA (16 ms) than for the 250-ms SOA (7 ms). More important, this analysis also yielded a significant SOA × Relatedness × Expectancy interaction, $F(2, 188) = 3.08$, $MS_e = 811$, indicating that the relatedness effect decreased across SOAs for the expected conditions but did not vary as a function of SOA for the unexpected conditions (see top half of Table 3). As noted in the introduction, the Relatedness × Expectancy × SOA interaction violates an important prediction of the two-process theory.

The overall ANOVA also yielded a significant Age × Expectancy × SOA interaction, $F(2, 188) = 3.87$, $MS_e = 1{,}107$. In order to further specify the nature of this interaction, a series of post hoc comparisons were conducted. When only the 250-ms and 1,000-ms SOAs were included in an overall analysis, the interaction among age, expectancy, and SOA did not reach significance ($F < 1.00$). Thus it appears that the expectancy effect builds up at a similar rate for younger and older adults across the 250-ms and 1,000-ms SOAs. However, when only the 1,000-ms and 1,750-ms SOAs were included in the ANOVA, the interaction among age, expectancy, and SOA was significant, $F(1, 94) = 4.58$, $MS_e = 1{,}146$. Moreover, separate analyses of the younger and older adults' data indicated that the effect of expectancy significantly decreased for the older adults across the 1,000-ms and 1,750-ms SOAs, $F(1, 47) = 5.82$, $MS_e = 1{,}528$, whereas, for the younger adults, the increase in the expectancy effect across these SOAs did not reach significance, $F(1, 47) = 2.01$, $MS_e = 594$. It is noteworthy, however, that this latter increase in the expectancy effect for the younger adults did reach significance with regard to the unrelated prime conditions only, $F(1, 47) = 4.56$, $MS_e = 1{,}347$. Thus the conclusion from this set of post hoc analyses regarding the overall Age × Expectancy × SOA interaction

Table 3
Mean Expectancy (Attentional) and Relatedness (Automatic) Effects as a Function of Age, Stimulus Onset Asynchrony, Expectancy, and Relatedness: Experiment 1

	Expected		Unexpected		Means	
Time	ON	%C	ON	%C	ON	%C
Relatedness (automatic) effects						
Younger adults						
250 ms	13	0	−2	−1	6	−1
1,000 ms	12	−1	−3	2	5	0
1,750 ms	−2	−1	2	0	0	0
M	8	−1	−1	0	4	0
Older adults						
250 ms	18	1	2	1	10	1
1,000 ms	1	1	18	1	10	1
1,750 ms	−2	−1	6	1	2	0
M	6	1	9	1	9	1
Expectancy (attentional) effects						
	Related		Unrelated		Means	
Younger adults						
250 ms	15	1	0	0	8	1
1,000 ms	26	1	11	4	18	3
1,750 ms	23	4	27	5	25	5
M	21	2	19	3	17	3
Older adults						
250 ms	12	3	−2	3	5	3
1,000 ms	17	3	34	3	26	3
1,750 ms	2	2	10	4	6	3
M	10	3	14	3	12	3

Note. ON = mean onset latency; %C = percentage correct.

was that there was little difference in the build-up of an expectancy effect between the 250-ms and 1,000-ms SOAs; however, there was a substantial age-related difference between the 1,000-ms and 1,750-ms SOAs. In other words, the expectancy effect significantly decreased for the older adults across these same SOAs, whereas for the younger adults, there was some evidence, at least from the unrelated prime conditions, that the expectancy effect increased.

Percentage correct. With regard to the accuracy data, the top half of Table 3 shows that there was very little impact of relatedness on accuracy. However, as shown in the bottom half of Table 3, both the younger and older adults responded with higher accuracy in the expected conditions than in the unexpected conditions. In addition, there appears to have been some build-up in the influence of expectancy across the SOAs for the younger adults, whereas for the older adults, the influence of expectancy remained rather stable across the three SOAs. The ANOVA on the percentage correct data yielded a main effect of expectancy, $F(1, 94) = 21.15$, $MS_e = 65.2$. Although the Age × Expectancy × SOA interaction did not reach significance, $F(2, 188) = 2.20$, $MS_e = 27.3$, $p = .11$, separate ANOVAs on the younger and older adults' accuracy data indicated that the Expectancy × SOA interaction was significant for the younger adults, $F(2, 94) = 4.42$, $MS_e = 47.5$, whereas this interaction did not approach significance for the older adults, $F(2, 94) < 1.00$. Thus in accordance with the results from the ANOVA on the response latency data, it appears that the influence of expectancy builds up across the SOAs for the younger adults but not for the older adults.

Noncategory Prime Conditions

Onset latencies. In Table 4 we display the mean onset latencies and percentages correct as a function of age, expectancy, and SOA for the noncategory prime conditions. As noted earlier, the importance of the noncategory prime conditions is that they provide a pure estimate of the influence of expectancy that was induced by the probability manipulation. On these trials, no information was provided by the prime (*READY*) to indicate which expectancy should be generated. Therefore, an expectancy effect for the noncategory prime conditions is attributable to the fact that the two expected categories were more likely to occur within a given block of trials than were the two unexpected categories. The major point to note in Table 4 is that the expectancy effect, induced by the simple probability manipulation, appears to have built up across SOAs for both younger and older adults. In addition, by comparing the bottom halves of Table 3 and Table 4, one can see that the overall expectancy effect is larger for the critical category prime conditions than for the noncategory prime conditions, $t(95) = 3.19$, $p < .01$. Thus there was a prime-induced expectancy effect that was above and beyond the probability-induced expectancy effect.

Table 4
Mean Onset Latency (ON) and Percentage Correct (%C) for the Noncategory Prime Conditions as a Function of Expectancy, Age, and Stimulus Onset Asynchrony: Experiment 1

	Expected		Unexpected		Difference	
Time	ON	%C	ON	%C	ON	%C
Younger adults						
250 ms	533	96	526	94	−7	2
1,000 ms	480	97	486	94	6	3
1,750 ms	480	96	490	96	10	2
M	498	96	501	95	3	2
Older adults						
250 ms	675	96	674	93	−1	3
1,000 ms	615	96	621	95	6	1
1,750 ms	608	97	622	94	14	3
M	633	96	639	94	6	2

The previous observations were supported by a 2 × 2 × 3 (Age × Expectancy × SOA) mixed-factor ANOVA. This analysis yielded significant main effects of age, $F(1, 94) = 56.02$, $MS_e = 47,855$, and SOA, $F(2, 94) = 102.06$, $MS_e = 1,671$. Both the main effect of expectancy, $F(1, 94) = 3.38$, $MS_e = 909$, $p = .065$, and the interaction between expectancy and SOA, $F(2, 188) = 3.01$, $MS_e = 1,093$, $p = .05$, approached significance. Planned comparisons indicated that only the 1,750-ms SOA produced a significant expectancy effect ($p < .01$).

Percentage correct. As shown in Table 4, the expected condition yielded higher accuracy than did the unexpected condition for both the younger and older adults. The only effect to reach significance in the ANOVA on the accuracy data was the main effect of expectancy, $F(1, 94) = 10.97$, $MS_e = 54.6$.

Discussion

A number of aspects of the results from Experiment 1 are noteworthy. First, with regard to our first goal of investigating the impact of prime–target relatedness, expectancy, and SOA in a task that does not involve postaccess search processes, the results overall appear to conform to the two-process theory of priming. The expectancy (attentional) effect increased across SOAs, whereas the relatedness effect appeared to decrease across SOAs. However, other aspects of these data do not fit within the two-process framework. Because the primary data source for the two-process theory has been young adults, and because age interacted with expectancy and SOA in these data, we emphasize primarily the younger adults' data. As shown in the upper half of Table 3, the relatedness effect decreased across SOAs for the expected conditions (15 ms), but not for the unexpected conditions (−4 ms). With regard to the expectancy effect in the bottom half of Table 3, the expectancy effect increased across SOAs primarily for the unrelated conditions (27 ms) and relatively little for the related conditions (8 ms). An ANOVA on only the younger adults' data yielded a significant Relatedness × Expectancy × SOA interaction, $F(2, 94) = 4.05$, $MS_e = 362$. As noted earlier, the fact that relatedness, expectancy, and SOA interact is problematic for an unembellished two-process model of priming. We return to this observation later.

With regard to the second goal of investigating age-related changes in the impact of relatedness, expectancy, and SOA, the results of Experiment 1 yielded an interaction among age, expectancy, and SOA. The data indicated that both groups of subjects produced larger expectancy effects for the 1,000-ms SOA than for the 250-ms SOA. However, the expectancy effect significantly decreased between the 1,000-ms and 1,750-ms SOAs for the older adults, whereas for the younger adults, the expectancy effect actually increased across these two SOAs, at least for the unrelated prime conditions. This interaction is intriguing because it suggests that the speeds of developing an expectancy were similar for the younger and older adults, as indicated by the pattern of data for the 250-ms and 1,000-ms SOAs, but that the older adults did not maintain, and appeared to actually lose, such an expectancy at the longer delay.

Experiment 2

Two issues were addressed in Experiment 2. First, we attempted to replicate the Relatedness × Expectancy × SOA interaction that we found in the data from the younger adults in Experiment 1. As noted earlier, this three-way interaction is problematic for the two-process theory of priming. Second, we attempted to further address the Age × Expectancy × SOA interaction obtained in Experiment 1.

In order to address this latter interaction, Experiment 2 involved two major changes. First, in Experiment 2 the primes were visually available throughout virtually all of a given SOA, as opposed to the presentation format used in Experiment 1, in which the primes were visually available for only 200 ms, independently of prime–target SOA. Because the primes were presented for only 200 ms in Experiment 1, subjects needed to retain the prime identity without direct stimulus support for an extended period of time. The cognitive load produced by retention of the prime identity should have been highest for the longest SOA. This additional load, along with the demands of the instructions for generating the correct expectancies, could have produced a sufficiently complex processing situation that may have exceeded the older adults' attentional capacity. There is considerable evidence in the literature that supports the notion that older adults show increasing deficits in performance as the cognitive complexity of a given task increases (see Salthouse, 1985, for a review). Thus in Experiment 2 the primes were displayed for all but 50 ms of each SOA. This procedure should have produced no additional load of remembering the prime identity for an extended period of time for the long SOA because the prime was visually available throughout virtually all of the prime–target SOA.

In addition to increasing the availability of prime information during the prime–target SOAs, Experiment 2 also included a wider range of SOAs. In Experiment 1 the SOAs were 250 ms, 1,000 ms, and 1,750 ms, whereas in Experiment 2 the SOAs were 250 ms, 1,750 ms, and 3,250 ms. An increase in the range of SOAs was used in Experiment 2 because it is possible that the Age × Expectancy × SOA interaction found in Experiment 1 was not caused by prime availability but, rather, may have been caused by the fact that older adults have relatively more difficulty maintaining an attentional expectancy for a given period of time (e.g., 1,750 ms). If this is the case, very little influence of expectancy would be expected for the older adults on either the 1,750-ms or the 3,250-ms SOAs in Experiment 2, even though the primes were visually available throughout most of the SOA.

In sum, the predictions in Experiment 2 are straightforward. If prime availability is the crucial factor that produced the Age × Expectancy × SOA interaction in Experiment 1, visual presentation of the primes throughout the prime–target SOAs should eliminate this interaction in Experiment 2. On the other hand, if there is a temporal limit for older adults in holding an attentional expectancy, the Age × Expectancy × SOA interaction that was found in Experiment 1 should be replicated.

Method

Subjects

Thirty-six young adults (10 men and 26 women) and 36 older adults (15 men and 21 women) participated in Experiment 2. The mean age for the younger adults was 24 years, and their ages ranged between 16 and 40 years; the mean age for the older adults was 72 years, and their ages ranged between 65 and 81 years. The older adults had slightly less formal education (14.2 years) than did the younger adults (15.6 years). The older and younger adults scored almost precisely the same on the vocabulary subsection of the WAIS (30.2 and 30.5 items correct, respectively). The only difference to reach significance across the two groups was in age.

Apparatus and Materials

The apparatus and materials used in Experiment 1 were used in Experiment 2.

Procedure

As noted, the two procedural differences in Experiment 2 were as follows: (a) The prime remained on the screen for all but 50 ms of the SOA, and (b) the SOAs were 250 ms, 1,750 ms, and 3,250 ms.

Results

Critical Target Conditions

Onset latencies. In Table 5 we present the mean onset latencies and percentages correct as a function of age, expect-

Table 5

Mean Onset Latency (ON) and Percentage Correct (%C) for the Target Words as a Function of Age, Stimulus Onset Asynchrony, Relatedness, and Expectancy: Experiment 2

	Related				Unrelated			
	Expected		Unexpected		Expected		Unexpected	
Time	ON	%C	ON	%C	ON	%C	ON	%C
Younger adults								
250 ms	545	97	554	92	552	95	559	94
1,750 ms	530	95	546	95	535	95	545	92
3,250 ms	521	96	540	97	520	96	556	91
Older adults								
250 ms	699	97	704	93	707	98	735	93
1,750 ms	660	97	694	96	675	97	710	94
3,250 ms	665	98	703	95	668	97	704	92

ancy, relatedness, and SOA for the critical targets. There are two major points to note about the onset latencies in Table 5. First, the older adults were again consistently slower than the younger adults. Second, as in Experiment 1, overall response latency decreased primarily between the short (250-ms) and medium (1,750-ms) SOAs, and this difference was slightly larger for older adults (27 ms) than for younger adults (16 ms).

Table 6 shows the mean relatedness and the expectancy effects as a function of age and SOA. There are four aspects to note in these data. First, the top half of the table shows that the overall relatedness effect decreased across the 1,750-ms SOA and the 3,250-ms SOA for the older adults but not for the younger adults. Second, in the bottom half of this table, there appears to have been a large impact of expectancy that, in general, increased across SOAs. Third, and most important, the older adults actually produced slightly larger expectancy effects at the longer (1,750-ms and 3250-ms) SOAs than did the younger adults. Finally, in only the younger adults' data, there was again some tendency for a Relatedness × Expectancy × SOA interaction; that is, as in Experiment 1, the relatedness effect primarily decreased across SOAs for the expected condition (8 ms), in comparison with the unexpected condition (−11 ms), and the expectancy effect primarily increased across SOAs for the unrelated conditions (29 ms), in comparison with the related conditions (10 ms).

The ANOVA yielded significant main effects of age, $F(1, 70) = 30.76$, $MS_e = 144{,}329$; of relatedness, $F(1, 70) = 7.24$, $MS_e = 2{,}306$; of expectancy, $F(1, 70) = 30.76$, $MS_e = 3{,}681$; and of SOA, $F(2, 140) = 11.19$, $MS_e = 3{,}829$. This analysis also yielded a significant Expectancy × SOA interaction, $F(2, 140) = 4.46$, $MS_e = 1{,}563$, indicating that the expectancy effect increased across SOAs. The interaction among age, expectancy, and SOA, which was significant in Experiment 1, did not approach significance, $F(2, 140) < 1.00$. Finally, an ANOVA on only the younger adults' data indicated that although the pattern of means was similar to that in Experiment 1, the overall Relatedness × Expectancy × SOA interaction did not reach significance, $F(2, 70) = 1.34$, $MS_e = 1{,}070$.

Table 6
Mean Expectancy (Attentional) and Relatedness (Automatic) Effects as a Function of Age, Stimulus Onset Asynchrony, Expectancy, and Relatedness: Experiment 2

	Expected		Unexpected		Means	
Time	ON	%C	ON	%C	ON	%C
Relatedness (automatic) effects						
Younger adults						
250 ms	7	2	5	−2	6	0
1,750 ms	5	0	−1	3	2	2
3,250 ms	−1	0	16	6	8	3
M	4	1	7	2	5	2
Older adults						
250 ms	8	−1	31	0	19	0
1,750 ms	15	0	16	2	16	1
3,250 ms	3	1	1	3	2	2
M	9	0	16	2	12	1
Expectancy (attentional) effects						
	Related		Unrelated		Means	
Younger adults						
250 ms	9	5	7	1	8	3
1,750 ms	16	0	10	3	13	2
3,250 ms	19	−1	36	5	28	2
M	15	1	18	3	16	3
Older adults						
250 ms	5	4	28	5	17	5
1,750 ms	34	1	35	3	35	2
3,250 ms	38	3	36	5	37	4
M	26	3	33	4	30	4

Table 7
Mean Onset Latency (ON) and Percentage Correct (%C) for the Noncategory Prime Conditions as a Function of Expectancy, Age, and Stimulus Onset Asynchrony: Experiment 2

	Expected		Unexpected		Difference	
Time	ON	%C	ON	%C	ON	%C
Younger adults						
250 ms	552	93	551	93	−1	0
1,750 ms	522	95	538	94	16	1
3,250 ms	522	96	535	93	13	3
M	532	95	541	93	9	2
Older adults						
250 ms	691	93	704	94	13	−1
1,750 ms	674	95	699	95	25	0
3,250 ms	678	95	696	94	18	1
M	681	94	700	94	19	0

Percentage correct. As shown in the upper half of Table 6, there does appear to have been a slight advantage in accuracy of the related condition over that of the unrelated condition. In addition, as shown in the bottom half of Table 6, the expected condition produced higher accuracy than did the unexpected condition. The ANOVA on the percentage correct data yielded a significant effect only of expectancy, $F(1, 70) = 13.21$, $MS_e = 76.5$.

Noncategory Prime Conditions

Onset latencies. In Table 7 we display the mean onset latencies for the noncategory prime conditions. The major point to note in this table is that again there appears to have been a build-up in the expectancy effect across SOAs, especially between the 250-ms and 1,750-ms SOAs, and this occurred to the same degree for younger and older adults. In addition, the bottom halves of Table 6 and Table 7 show that the overall expectancy effect was again larger in the critical category conditions than in the noncategory prime conditions, $t(71) = 1.96$, $p = .05$. Thus there was again evidence of a prime-induced expectancy effect above and beyond the probability-induced expectancy effect.

The ANOVA on the noncategory prime trials yielded main effects of age, $F(1, 70) = 33.74$, $MS_e = 75{,}585$; of expectancy, $F(1, 70) = 22.16$, $MS_e = 934$; and of SOA, $F(2, 140) = 6.53$, $MS_e = 1{,}975$. Although the Expectancy × SOA interaction did not reach significance, planned comparisons indicated that the main effect of expectancy did not reach significance at the 250-ms SOA, $t(71) < 1.00$, but it was significant for both the 1,750-ms SOA, $t(71) = 2.55$, and the 3,250-ms SOA, $t(71) = 2.08$. Thus as in Experiment 1, the impact of the probability manipulation for the noncategory primes was significant only for the longer SOAs.

Percentage correct. As shown in Table 7, there does appear to have been some slight advantage for the expected condition that built up across SOAs for both groups of subjects. However, the ANOVA did not yield any significant effects or interactions for the accuracy data.

Discussion

One motivation for conducting Experiment 2 was to determine whether older adults produced the smaller expectancy effect at the 1,750-ms SOA in Experiment 1 because (a) the prime was presented for only 200 ms, and hence subjects had to retain both the prime identity and the instructional manipulation for a full 1,550 ms, or (b) there is a simple time limit to the duration that older adults can hold an expectancy, independently of the presence of the prime, and that limit was exceeded by the 1,750-ms SOA used in Experiment 1. In order to distinguish between these two possibilities, the primes were presented in Experiment 2 for all but 50 ms of the SOA, and also the range of SOAs was increased. The results of Experiment 2 clearly indicate that when older adults do not have to retain the prime information, they produce quite large expectancy effects for both the 1,750-ms SOA and the 3,250-ms SOA. In fact, a comparison of older adults' performances in the same 1,750-ms SOA in Experiments 1 and 2 produces a significant Experiment × Expectancy interaction, $F(1, 82) = 6.14$, $MS_e = 2,843$, indicating a larger expectancy effect in Experiment 2 when the primes were visually available for 1,700 ms, in comparison with Experiment 1 when the primes were visually available for only 200 ms. A similar comparison at the 250-ms SOA for the older adults did not approach significance, $F(1, 82) < 1.00$. It is also noteworthy that the younger adults actually produced a slightly smaller expectancy effect in Experiment 2 for the 1,750-ms SOA, in comparison with Experiment 1, although this difference did not reach significance, $F(1, 82) = 3.20$, $MS_e = 906$. Thus these results provide strong support for the notion that the decreased impact of expectancy at the 1,750-ms SOA for the older adults in Experiment 1 was a result of the primes' not being visually available throughout the SOA. It is clear that when the primes were available, older adults produced as large of an expectancy effect as did younger adults for relatively long SOAs.

A second goal of Experiment 2 was to further address the Relatedness × Expectancy × SOA interaction that appeared in the young adults' data in Experiment 1. As shown in the younger adults' data in Table 6, the relatedness effect decreased across SOAs primarily in the expected conditions, whereas the expectancy effect increased across SOAs primarily in the unrelated conditions. Although the three-way interaction among relatedness, expectancy, and SOA did not reach significance in Experiment 2, the fact that the same patterning of means was found in both experiments provides further evidence of an interactive influence of relatedness, expectancy, and SOA. As noted earlier, such an interaction calls into question the independence of the automatic and attentional mechanisms that are assumed to underlie semantic priming effects. We return to this issue later.

Experiment 3

Although the results of Experiment 2 suggest that prime duration was the crucial element that produced the Age × Expectancy × SOA interaction in Experiment 1, a second variable changed across the first two experiments: the range in prime–target SOAs. It is possible that the change in the range of SOAs could have produced the different pattern of results. For example, because the prime–target SOAs were greater in Experiment 2, older adults may have benefited from the longer practice in directing attention to the expected categories. In fact, the overall expectancy effect for the older adults was larger in Experiment 2 (30 ms) than in Experiment 1 (12 ms). In order to address the possibility that a change in range of SOAs was a factor contributing to the change in results across the first two experiments, Experiment 3 involved the same range of SOAs used in Experiment 2, but now the primes were presented for only 200 ms, as in Experiment 1. The predictions are again straightforward. If prime duration is the crucial element that produced differences across Experiments 1 and 2, an Age × Expectancy × SOA interaction would again be expected with the short prime durations used in Experiment 3. However, if the change in the range of SOAs is the crucial factor across the first two experiments, no evidence of an Age × Expectancy × SOA interaction would be expected in Experiment 3. Finally, this experiment again affords an opportunity to provide further information regarding the independence of the automatic and attentional mechanisms through a test of the interaction of relatedness, expectancy, and SOA in the younger adults' data.

Method

Subjects

Thirty-six younger adults (23 women and 13 men) and 36 older adults (20 women and 16 men) participated in Experiment 3. The mean age of the younger adults was 19.5 years, and their ages ranged between 17 and 33 years; the mean age for the older adults was 69.9 years, and their ages ranged between 60 and 83 years. The mean education levels were 13.9 years for the younger adults and 14.4 years for the older adults. The mean scores on the vocabulary subsection of the WAIS were 28.4 for the young adults and 29.4 for the older adults. The only difference to reach significance across the two groups was in age.

Apparatus, Materials, and Procedure

As noted earlier, the only difference between Experiments 2 and 3 is that the primes were visually available for only 200 ms in Experiment 3.

Results

Critical Targets

Onset latencies. In Table 8 we display the mean onset latencies and percentage correct as a function of age, related-

Table 8
Mean Onset Latency (ON) and Percentage Correct (%C) for the Target Words as a Function of Age, Relatedness, Expectancy, and Stimulus Onset Asynchrony: Experiment 3

	Related				Unrelated			
	Expected		Unexpected		Expected		Unexpected	
Time	ON	%C	ON	%C	ON	%C	ON	%C
Younger adults								
250 ms	506	96	532	95	531	92	525	93
1,750 ms	485	96	505	96	489	95	497	92
3,250 ms	482	96	509	92	482	95	508	93
Older adults								
250 ms	767	95	779	92	778	93	783	90
1,750 ms	680	96	734	94	708	94	745	92
3,250 ms	692	98	715	95	709	95	734	91

ness, expectancy, and SOA. Two aspects of these data to note had been found in the previous two experiments: First, older adults were again slower than younger adults; second, older adults produced a larger decrease in response latency (60 ms) between the 250-ms and the 1,750-ms SOAs than did the younger adults (30 ms).

Table 9 shows the mean relatedness and expectancy effects as a function of age and SOA. As shown in the top half of this table, the relatedness effects were rather small and inconsistent across SOAs. As in the two previous experiments, the relatedness effect for the younger adults appears to have decreased across SOAs for the expected conditions but not for the unexpected conditions. The older adults produced an inconsistent pattern across SOAs. The expectancy effects in the bottom half of Table 9 show the same pattern that was found in Experiment 1: Younger adults overall produced an increasing expectancy effect across the SOAs (primarily for the unrelated conditions), whereas older adults produced an increase in the expectancy effect between the 250-ms and 1,750-ms SOAs, but then the expectancy effect appears to have decreased at the longest SOA.

The ANOVA on the onset latency data yielded main effects of age, $F(1, 70) = 80.26$, $MS_e = 143{,}861$; of relatedness, $F(1, 70) = 10.74$, $MS_e = 1{,}435$; of expectancy, $F(1, 70) = 30.96$, $MS_e = 3{,}145$; and of SOA, $F(2, 140) = 42.30$, $MS_e = 4{,}724$. The ANOVA also yielded five interactions: (a) An Age × Relatedness interaction, $F(1, 70) = 6.01$, $MS_e = 1{,}435$, indicated that older adults produced a larger overall relatedness effect than did younger adults. (b) A Relatedness × Expectancy interaction, $F(1, 70) = 4.14$, $MS_e = 1{,}492$, indicated that the expectancy effect was larger for the related conditions (27 ms) than for the unrelated conditions (16 ms). (c) An Age × SOA interaction, $F(2, 140) = 5.75$, $MS_e = 4{,}724$, indicated that response latencies decreased between the 250-ms and the 1,750-ms SOAs more for the older adults than for the younger adults. (d) An Expectancy × SOA interaction, $F(2, 140) = 5.72$, $MS_e = 1{,}485$, indicated that the expectancy effect increased across SOAs. (e) Of most importance, an Age × Expectancy × SOA interaction, $F(2, 140) = 4.53$, $MS_e = 1{,}485$, as shown in the bottom half of Table 9, primarily reflected the fact that the expectancy effect increased across SOAs for the younger adults, whereas for the older adults, the expectancy effect increased between the short and medium SOAs but then decreased at the longest SOA. Finally, in order to test whether there are interactive effects of relatedness, expectancy, and SOA, a separate ANOVA on only the younger adults' data again yielded a significant Relatedness × Expectancy × SOA interaction, $F(2, 70) = 3.81$, $MS_e = 600$.

Percentage correct. As shown in Table 9, there appears to have been an impact of relatedness and expectancy on accuracy, but these effects do not appear to have been modulated by the other variables. In accordance with this observation, the ANOVA on the percentage correct data yielded main effects only of relatedness, $F(1, 70) = 16.77$, $MS_e = 42.7$, and expectancy, $F(1, 70) = 15.64$, $MS_e = 45.3$.

Noncategory Prime Trials

Onset latencies. The onset latencies for the noncategory prime condition are displayed in Table 10. The major point to note in this table is that the expected categories produced faster overall response latencies than did the unexpected categories. In addition, the bottom halves of Table 9 and Table 10 show again that the expectancy effect for the category prime trials was larger than for the noncategory prime trials, $t(71) = 3.36$, $p = .001$. Thus there was a prime-induced expectancy above and beyond the probability-induced expectancy.

Table 9
Mean Expectancy (Attentional) and Relatedness (Automatic) Effects as a Function of Age, Expectancy, Relatedness, and Stimulus Onset Asynchrony: Experiment 3

	Expected		Unexpected		Means	
Time	ON	%C	ON	%C	ON	%C
Relatedness (automatic) effects						
Younger adults						
250 ms	25	4	−7	2	9	3
1,750 ms	4	1	−8	4	−2	3
3,250 ms	0	1	−1	−1	−1	0
M	10	2	−5	2	2	2
Older adults						
250 ms	11	2	4	2	8	2
1,750 ms	28	2	11	2	20	2
3,250 ms	17	3	19	4	18	4
M	19	2	11	3	21	0
Expectancy (attentional) effects						
	Related		Unrelated		Means	
Younger adults						
250 ms	26	1	−6	−1	10	0
1,750 ms	20	0	8	3	14	2
3,250 ms	27	4	26	2	27	3
M	24	2	9	1	17	2
Older adults						
250 ms	12	3	5	3	9	3
1,750 ms	54	2	37	2	46	2
3,250 ms	23	3	25	4	24	4
M	30	3	22	3	26	3

Note. ON = mean onset latency; %C = percentage correct.

Table 10
Mean Onset Latency (ON) and Percentage Correct (%C) for the Noncategory Prime Conditions as a Function of Expectancy, Age, and Stimulus Onset Asynchrony: Experiment 3

	Expected		Unexpected		Difference	
Time	ON	%C	ON	%C	ON	%C
Younger adults						
250 ms	509	94	521	94	12	0
1,750 ms	472	95	478	95	6	0
3,250 ms	477	96	484	96	7	0
M	486	95	494	95	8	0
Older adults						
250 ms	760	95	765	90	5	5
1,750 ms	699	93	703	93	4	0
3,250 ms	697	90	696	93	−1	−3
M	719	93	721	92	3	1

The ANOVA yielded main effects of age, $F(1, 70) = 76.59$, $MS_e = 747{,}362$, and of SOA, $F(2, 140) = 41.15$, $MS_e = 2{,}999$. The main effect of expectancy only approached significance, $F(1, 70) = 3.39$, $MS_e = 816$, $p = .066$. Finally, the ANOVA also yielded an Age × SOA interaction, $F(2, 140) = 3.35$, $MS_e = 2{,}999$, indicating that again the older adults' response latency decreased more between the 250-ms and 1,750-ms SOAs (62 ms) than did that of the younger adults (40 ms).

Percentage correct. As shown in Table 10, there was no influence of expectancy for the younger adults. However, for the older adults, there was actually a decreased expectancy effect across the SOAs. The ANOVA did not yield any significant main effects or interactions.

Discussion

The results of Experiment 3 replicated the important Age × Expectancy × SOA interaction found in Experiment 1. Thus the change in the range of SOAs between Experiments 1 and 2 was not the crucial variable that eliminated the Age × Expectancy × SOA interaction in Experiment 2. It appears that the prime duration was the variable that modulated the effect; that is, with the same SOAs used in Experiment 2 but the same prime durations used in Experiment 1, Experiment 3 replicated the Age × Expectancy × SOA interaction found in Experiment 1. In addition, the Relatedness × Expectancy × SOA interaction was again replicated in the younger subjects' data. Specifically, the relatedness effect decreased across SOAs primarily for the expected conditions, and the expectancy effect increased across SOAs primarily for the unrelated conditions.

General Discussion

In discussing this research, we focus on the two major issues presented in the introduction. First, we discuss the implications of these results for the two-process model of priming. Then we discuss the implications of the results with regard to age-related changes in the rate of attentional build-up.

Implications for the Two-Process Model of Semantic Priming Effects

In the introduction, we argued that an important aspect of this research is an extension of the two-process framework to the pronunciation task. As noted, the three previous studies that included a factorial crossing of expectancy, relatedness, and SOA in order to discriminate between automatic and attentional mechanisms in the semantic priming task all relied on the LDT. Recent priming research has indicated that the LDT is contaminated by a third component, involving a postaccess checking process, that could have influenced performance in these previous experiments. Thus it was necessary to extend this work to a task that minimized the postaccess checking processes: the pronunciation task. Because age seems to modulate the expectancy effect, and because the primary data base regarding the two-process model involves younger adults, we emphasize primarily the data from the younger adults in this discussion.

At first glance, the results appear to be rather consistent with those of past studies in this area and with the two-process model. First, consider the impact of relatedness. Overall, there was a small impact of relatedness in our experiments, which was expected because priming effects from category names to high- and medium-category exemplars are rather small in the pronunciation task (e.g., Balota & Duchek, 1988). More important, with respect to the predictions of the two-process model, this small impact of relatedness decreased across SOAs in each experiment for the critical targets, the only exception being the critical targets in Experiment 2 (see Table 6).[1] Therefore, the data for the younger subjects overall indicate that the relatedness effect, presumably a reflection of automatic spreading activation, is fast acting and appears to decrease across SOAs.

Next, consider the impact of expectancy. First, the expectancy effects were, overall, considerably larger than the relatedness effects. Moreover, the time course of the expectancy effect was consistent with the two-process model; that is, in

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[1] Actually, there is further evidence available in these data regarding the decrease in the relatedness effect across the expected conditions. Specifically, the buffer trials consisted of related and unrelated prime–target pairs from the two expected categories within a block of trials. Although the items that served in the buffer trials were not counterbalanced across the critical target conditions, these items were completely counterbalanced across both relatedness and SOAs. Hence the buffer trials provide further evidence regarding whether the relatedness effect was consistently decreasing across SOAs for the expected conditions. The results of such analyses indicated that in every experiment, for both the younger and older adults, the relatedness effect for the buffer items decreased across SOAs. Because age was not included in any interactions, we present the means collapsed across age groups. The mean relatedness effects for Experiment 1 were 17 ms (2%) at the 250-ms SOA, 8 ms (1%) at the 1,000-ms SOA, and 7 ms (1%) at the 1,750-ms SOA. The mean relatedness effects for Experiment 2 were 12 ms (0%) at the 250-ms SOA, 10 ms (1%) at the 1,750-ms SOA, and 6 ms (0%) at the 3,250-ms SOA. The mean relatedness effects for Experiment 3 were 17 ms (2%) at the 250-ms SOA, 10 ms (1%) at the 1,750-ms SOA, and 8 ms (2%) at the 3,250-ms SOA.

each experiment for both category prime trials and the noncategory prime trials, the expectancy effect increased across SOAs for the young subjects, the only exception being the noncategory prime conditions in Experiment 3 (see Table 10). Of course, one of the major tenets of the two-process model is that the attentional mechanism takes time to engage.

At this level, the results from the younger adults appear to be quite consistent with the two-process model. However, one aspect of these data is inconsistent with the two-process model: Within the two-process model, a three-way interaction among prime–target expectancy, relatedness, and SOA would not be expected. The relatedness effect should decrease across SOAs independently of expectancy, and the expectancy effect should increase across SOAs independently of relatedness. This, in fact, is a crucial prediction of the two-process model, and as noted in the introduction, the independence of the automatic and attentional components has been quite influential in the development of arguments concerning the modularity of the lexical processing system. Specifically, relatedness effects attributable to automatic spreading activation should be independent of attentional expectancies in a self-encapsulated modular lexicon.

Such independence, however, is not evident in the younger adults' data in Tables 3, 6, and 9. Specifically, the relatedness effect decreased across SOAs primarily in the expected conditions, whereas the expectancy effect increased across SOAs primarily in the unrelated conditions. In fact, an ANOVA on the younger adults' data yielded significant Relatedness × Expectancy × SOA interactions for both Experiments 1 and 3, and the same pattern was found in Experiment 2, although the three-way interaction did not reach significance in this experiment. The overall interactive pattern of these three variables was clearly quite consistent across the results of these experiments and was inconsistent with the predictions of the two-process model.[2]

The important question now becomes whether this particular interaction simply resulted from the use of a pronunciation task and hence was not found in the previous lexical decision studies (Burke et al., 1987; Favreau & Segalowitz, 1983; Neely, 1977). It is also possible, however, that in Neely's study and in Favreau and Segalowitz's study, such a pattern was not detected because in both studies the emphasis was on facilitation and inhibition effects in comparison to a neutral baseline, as opposed to direct comparisons of the relevant conditions, as in our study. Moreover, Burke et al. may not have detected this pattern because the emphasis in their study was on the interaction among these variables and age.

In order to address the possibility that similar patterns were present in the previous lexical decision studies, we tabulated the relevant data from these studies (Tables 11 and 12).[3] Of interest is that the data from these studies were remarkably similar to the data obtained in our experiments. First, consider the relatedness effects shown in Table 11. The mean relatedness effect consistently decreases more as a function of SOA in the expected conditions (*M* across studies = 38 ms) than in the unexpected conditions (*M* across studies = −9 ms). In fact, the relatedness effect did not decrease at all in the unexpected conditions. Second, with regard to the expectancy effects displayed in Table 12, the mean expectancy effects consistently increased more as a function of SOA in the unrelated conditions (*M* across studies = 104 ms) than for the related conditions (*M* across studies = 58 ms). It is remarkable that this same pattern has been found in all seven experiments (a total of 332 young adults) in which relatedness, expectancy, and SOA were factorially crossed.

Thus these data indicate that the influence of expectancy, relatedness, and SOA do not appear to have been independent for young adults. This, of course, is problematic for an unembellished two-process account. Specifically, relatedness apparently was modulated by subjects' expectancies and hence was not simply a reflection of a purely "automatic" spreading-activation mechanism within a self-encapsulated modular lexicon. Likewise, the build-up of expectancy across SOAs was much stronger for unrelated conditions than for related conditions. Hence the manner in which subjects directed attention appears to have been modulated by the presence of pre-existing pathways.

These data may be interpreted from two perspectives. Specifically, one can consider the data from the perspective of the expectancy effects and address the reason why the expectancy effects were modulated by relatedness and SOA. Likewise, one can also consider the data from the perspective of the relatedness effects and address the reason why the impact of relatedness was modulated by expectancy and SOA. Although only one of these perspectives is necessary to account for the three-way interaction, both are presented because (a) both are equally plausible on the basis of the available data and (b) each perspective emphasizes the interactive nature of spreading activation and attentional direction.

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[2] One might argue that because both the unrelated-expected condition and the related-unexpected conditions involved subjects receiving shift instructions, whereas the related-expected and the unrelated-unexpected conditions did not involve shift instructions, there was a confounding between shift and the comparisons of interest. It is possible that the instructions to shift attention when subjects received a given prime placed demands on capacity and hence would have produced an overall slowdown in performance even before the target was presented. In order to address this possibility, we collapsed the data across the two shift conditions and the two nonshift conditions for the short SOA. The result of this comparison indicated that for all subjects, performance in the shift condition was only 4 ms slower than in the nonshift condition. Moreover, if one looks at the difference between shift and nonshift conditions for the short SOA in Neely's (1977) study, one finds that there was virtually no difference across these conditions. Thus shift per se did not strongly modulate these data.

[3] Because the primary question of interest in this discussion involves a test of the two-process model, the data presented in Tables 11 and 12 include neither (a) data from older adults in our study or in Burke, White, and Diaz's (1987) study nor (b) data from Favreau and Segalowitz's (1983) study, in which bilingual subjects produced their second language. These data were excluded because in both cases there was evidence that these groups produced a qualitatively different pattern of attentional effects. The primary question is whether there is substantial evidence for the unembellished two-process model with younger subjects who produced their primary language. All available data that we are aware of and that include the necessary conditions to fully address this issue are presented in Tables 11 and 12.

Table 11
Mean Relatedness Effects as a Function of Expectancy and Stimulus Onset Asynchrony (SOA)

	Naming			Lexical decision			
						Favreau & Segalowitz (1983)	
Mean effect size	Exp. 1	Exp. 2	Exp. 3	Neely (1977)	Burke, White, & Diaz (1987)	Equal[a]	Unequal[a]
			Expected				
1st SOA	250	250	250	250	410	200	200
Mean onset latency	13	7	25	27	42	44	62
% Correct	0	2	4	3	1	−1	−1
2nd SOA	1,000	1,750	1,750	400	1,550	1,150	1,150
Mean onset latency	12	5	4	53	−3	−19	−16
% Correct	−1	0	1	3	−1	−1	1
3rd SOA	1,750	3,250	3,250	700	—	—	—
Mean onset latency	−2	−1	0	0			
% Correct	−1	0	1	2			
4th SOA	—	—	—	2,000	—	—	—
Mean onset latency				−5			
% Correct				1			
Change across SOAs[b]	15	8	25	32	45	63	78
			Unexpected				
1st SOA	250	250	250	250	410	200	200
Mean onset latency	−2	5	−7	17	44	118	96
% Correct	−1	−2	2	2	14	−2	−3
2nd SOA	1,000	1,750	1,750	400	1,550	1,150	1,150
Mean onset latency	−3	−1	−8	41	37	147	127
% Correct	2	3	4	5	3	0	−1
3rd SOA	1,750	3,250	3,250	700	—	—	—
Mean onset latency	2	16	−1	23			
% Correct	0	6	−1	2			
4th SOA	—	—	—	2,000	—	—	—
Mean onset latency				8			
% Correct				0			
Change across SOAs[b]	−4	−11	6	9	7	−29	−31

Note. Exp. = Experiment (this study).
[a] Reading rate (bilingual subjects). [b] Shortest SOA minus longest SOA.

First, consider the data from the perspective of the expectancy effects. There was a greater build-up of expectancy across SOAs for the unrelated prime–target pairs than for the related prime–target pairs. This suggests that the allocation of attention (i.e., the build-up of expectancy) takes considerably more time for novel memory configurations than for pre-existing memory configurations. Post hoc, this seems quite reasonable. One might argue that in order to have developed semantic/lexical pathways in memory, subjects previously had to direct attention to the relations between these representations. Hence related prime–target pairs may be relatively uninfluenced by the amount of time to direct attention to these pathways. Stated very simply, there was less impact of SOA on the expectancy effect for related conditions simply because attention has been directed to such pathways consistently in the past and because the direction of attention to such pathways no longer demanded considerable time and resources. On the other hand, for the unrelated conditions, the direction of attention demanded considerable time to build up because the subjects had not had pre-experimental experience directing attention to such relations. Under these conditions, the subject was forced to construct (attend to) the correct prime–target relation on-line.

Second, consider the data from the perspective of the relatedness effects. The relatedness effects primarily decreased across SOAs for the expected conditions and not for the unexpected conditions. These data, collapsed across experiments in Table 11, further reveal that the relatedness effect for the short SOA in the expected conditions was 31 ms, whereas in the unexpected conditions it was 39 ms. However, for the long SOA, the relatedness effects were −7 ms in the expected conditions and 48 ms in the unexpected conditions. Thus the relatedness effects appear to have been quite consistent for both expected and unexpected conditions with the short SOA; however, with the long SOA there was a larger decrease in the relatedness effect for the expected conditions than in the unexpected conditions. This pattern might be explained in the following manner: For the short SOA, relatedness appears to have an impact independent of subjects' expectancies, as predicted by the two-process model (although see the caveat later regarding task differences). However, with the long SOA, subjects had time to engage attentional expec-

Table 12
Mean Expectancy Effects as a Function of Relatedness and Stimulus Onset Asynchrony (SOA)

	Naming			Lexical decision			
						Favreau & Segalowitz (1983)	
Mean effect size	Exp. 1	Exp. 2	Exp. 3	Neely (1977)	Burke, White, & Diaz (1987)	Equal[a]	Unequal[a]
			Related				
1st SOA	250	250	250	250	410	200	200
Mean onset latency	15	9	26	11	67	−14	−14
% Correct	1	5	1	0	1	1	2
2nd SOA	1,000	1,750	1,750	400	1,550	1,150	1,150
Mean onset latency	26	16	20	56	93	103	140
% Correct	1	0	0	2	1	−1	2
3rd SOA	1,750	3,250	3,250	700	—	—	—
Mean onset latency	23	19	27	67			
% Correct	4	−1	4	3			
4th SOA	—	—	—	2,000	—	—	—
Mean onset latency				90			
% Correct				7			
Change across SOAs[b]	8	10	1	79	26	131	154
			Unrelated				
1st SOA	250	250	250	250	410	200	200
Mean onset latency	0	7	−6	1	69	43	20
% Correct	0	1	−1	−1	15	0	0
2nd SOA	1,000	1,750	1,750	400	1,550	1,150	1,150
Mean onset latency	11	10	8	44	133	257	283
% Correct	4	3	3	4	4	1	1
3rd SOA	1,750	3,250	3,250	700	—	—	—
Mean onset latency	27	36	26	90			
% Correct	5	5	2	3			
4th SOA	—	—	—	2,000	—	—	—
Mean onset latency				103			
% Correct				6			
Change across SOAs[b]	27	29	32	102	64	214	263

Note. Exp. = Experiment (this study).
[a] Reading rate (bilingual subjects). [b] Shortest SOA minus longest SOA.

tancies. Hence expectancy was exerting the primary force for the long SOA. For the expected conditions, relatedness had relatively little impact at the long SOA because subjects actually received what they expected, and, as noted, expectancy was exerting the primary force at the long SOA. On the other hand, for the unexpected conditions, relatedness might still have had some impact because subjects actually did not receive what they expected and hence were forced to rely on whatever information that was still available to make the correct response. One piece of useful information that was still available in the lexical/semantic system was the preexisting prime–target relation. Thus a relatedness effect still occurred in the unexpected condition with the long SOA.

The current account of the Relatedness × Expectancy × SOA interaction still assumes two mechanisms: spreading activation and attentional expectancies. We have simply provided a more detailed account of how these two mechanisms temporally interact. The major embellishments are quite simple: First, the temporal courses of the direction of attention are quite different for pre-existing pathways and novel representations. Second, prime–target relatedness can still facilitate response latency after long delays, when attentional expectancies have not been confirmed. Thus although the interactive effects of relatedness, expectancy, and SOA are problematic for an unembellished two-process model, these effects can be handled either from a perspective that emphasizes the modulation of the relatedness effects by expectancy and SOA or from a perspective that emphasizes the modulation of the expectancy effects by relatedness and SOA. In either case, these data clearly indicate that the mechanisms underlying relatedness and expectancy effects are not independent.

The interdependence between spreading-activation mechanisms and attentional mechanisms is also supported by results of recent studies reported by Carr and Dagenbach (1990) and Dagenbach, Carr, and Wilhelmsen (1989). In both of these studies, the authors found evidence that the method of setting thresholds in a masked priming paradigm (see Balota, 1983; Fowler, Wolford, Slade, & Tassinary, 1981; Marcel, 1983) modulated the pattern of semantic priming effects. Specifically, if a presence/absence detection task is used to determine subjects' thresholds, one finds normal *facilitation* of related prime–target pairs, in comparison with unrelated prime–target pairs in a later masked priming paradigm. However, if subjects are asked to determine which of two clearly presented response alternatives is more similar in meaning to the masked stimulus (a semantic similarity judgment), then one finds *inhibition* in a later masked priming paradigm. The importance of this observation for our work is straightforward: Strategic attentional processing induced by different threshold-setting tasks influenced the pattern of "unconscious" automatic priming effects in a highly masked priming paradigm. As Carr and Dagenbach (1990) pointed out, these data provide support for the notion of interactive influences of attentional and automatic processes. At this level, these studies are quite consistent with our arguments.

Finally, with regard to the issue of task differences, the Relatedness × Expectancy × SOA interaction appears to have occurred in both pronunciation and lexical decision studies. There is, however, an important difference across tasks. As shown in Table 11, the relatedness effect in the pronunciation experiments was consistently smaller for the short SOA for the unexpected conditions than for the expected conditions ($p < .001$), thereby indicating that expectancy was modulating the relatedness effect at the short (250-ms) SOA. This pattern is particularly problematic for the notion of a self-encapsulated lexical module. However, this pattern did not occur in the lexical decision experiments. It is possible that the backward checking process in the LDT may have had a role in the short SOA for both the expected and unexpected conditions, thereby producing equivalent relatedness effects. However, with the exception of this important difference, the overall pattern appears to have been quite similar across tasks, especially with regard to the Relatedness × Expectancy × SOA interaction. Hence at this point it might be useful to emphasize the similarities in the data rather than the differences. This is especially the case because there has yet to be a direct comparison of lexical decision and pronunciation under identical stimulus conditions.

Age-Related Changes in the Build-Up of Expectancy

In addition to providing basic information regarding the relation among relatedness, expectancy, and SOA, our experiments also provided information regarding age-related changes in the build-up of attentional expectancies. The results were quite clear on this issue. In Experiment 1, there was a reliable Age × Expectancy × SOA interaction, indicating that younger adults produced an overall increasing influence of expectancy across the SOAs, whereas the older adults produced the largest expectancy effect with the intermediate SOA, and this effect actually decreased with the longest SOA. In Experiment 2, the range of SOAs was increased along with the visual availability of the prime during a given SOA. The results of this experiment indicated no Age × Expectancy × SOA interaction; that is, both the younger and older adults produced the largest expectancy effects for the longest SOA and the smallest expectancy effects for the shortest SOA. In Experiment 3, we used the same SOAs as in Experiment 2, but primes were visually available for only 200 ms across SOAs, as in Experiment 1. The Age × Expectancy × SOA interaction found in Experiment 1 was replicated. For the younger adults, the expectancy effect again increased across SOAs, whereas for the older adults, the expectancy effect increased between the short and medium SOAs and then decreased at the longest SOA. Thus the age-related change in the expectancy effect across SOAs appears to be tied to the availability of the prime item during the SOA.

An important issue that needs to be addressed here is why older adults had difficulty maintaining the prime-based expectancy at the 1,750-ms SOA in Experiment 1, whereas in Experiment 3 they produced a large expectancy effect for the 1,750-ms SOA and a smaller one for the 3,250-ms SOA. The critical difference here may be the within-experiment range of SOAs. A comparison of the overall expectancy effects for the older adults in Experiments 2 and 3 (see Tables 6 and 9) with the overall expectancy effect for the older adults in Experiment 1 (see Table 3) reveals that there was a considerably larger expectancy effect in Experiments 2 and 3 (30 and 26 ms, respectively) than in Experiment 1 (12 ms). It is possible that because there was a larger range of SOAs in Experiments 2 and 3, older adults benefited from receiving the increased practice at maintaining one of the two category expectancies at the longer SOAs for a given block of trials. This may have served to make the two expected categories of a given block of trials more salient and thereby increased the overall expectancy effect, as the results indicated. Moreover, this may also have served to increase the likelihood of maintaining an expectancy at the 1,750-ms SOA in Experiments 2 and 3. Although this account is admittedly ad hoc, the noteworthy empirical observation is that there was an increased overall expectancy effect in Experiments 2 and 3, in comparison with Experiment 1, and therefore it is not surprising that older adults were able to maintain an expectancy at a longer SOA in Experiment 3 than in Experiment 1. Obviously, the important point is that for the older adults, the expectancy effect *decreased* by 20 and 22 ms across the intermediate and long SOAs in Experiments 1 and 3, respectively, whereas in the same experiments for the younger adults, the expectancy effect *increased* by 7 and 13 ms. This pattern was not found when the primes were visually available throughout the prime delays in Experiment 2.[4]

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[4] It is interesting that this age-related change in the expectancy effect for the longest SOA is apparently not related to simply the "demands" of the expectancy manipulation. As we noted in the previous section, the expectancy effect builds up more strongly across SOAs for younger adults in the unrelated conditions than in the related conditions. We suggested that this finding was attributable to differences in the demands of directing attention to novel prime–target representations in the unrelated conditions in comparison with pre-existing prime–target representations in the related conditions. If the direction of attention to novel prime–target representations is more complex or places more demands on capacity than the direction of attention to pre-existing representations, one might expect that the older adults would show the decreased expectancy effect for the longest SOAs primarily in the unrelated prime–target conditions. However, as shown in Tables 3 and 9, the decreased expectancy effects for the longest SOA were equivalent for the related and unrelated conditions. Thus the processing demands of generating expectancies do not appear to be an adequate account of this age-related difference. Our results appear to be most consistent with an increased probability of loss of prime information during the longest SOAs in older adults.

A second aspect of the data that is consistent with the notion of an age-related loss in prime information is the data from the noncategory prime conditions. The noncategory primes simply reflect overall probability differences between expected and unexpected prime–target pairs within a block of trials. On these trials, there was no direct evidence from the prime with regard to which category to expect. Even though both Experiments 1 and 3 provided evidence of an Age × Expectancy × SOA interaction when the primes were presented to direct attention, neither of these experiments provided evidence for such an interaction when the primes were not directly presented (i.e., on the noncategory prime trials). It is possible that the expectancy effects on the noncategory prime trials reflect, at least in part, a passive accumulation of frequency information regarding which two of the four potential categories are most likely to occur within a given block of trials. In fact, there is evidence that judgment of frequency/probability estimates is intact in older adults (see Hasher & Zacks, 1979). Our data could be viewed as consistent with this finding. The important point is that the noncategory prime data provide converging evidence that the Age × Expectancy × SOA interactions were attributable to a loss of the category expectancy induced by the prime information.

Interestingly, the results of a recent study by Amrhein, Stelmach, and Goggin (1991) converge on the notion that older adults have difficulty maintaining an expectancy based on prime information. In that study, subjects were given 200-ms precues (primes) that were followed by a dark interval of 250, 500, 750, or 1,000 ms. The dark intervals were then followed by a target stimulus that specified the characteristics of a hand movement. On 75% of the trials, the precue specified the correct movement plan, and on 25% of the trials, the precue indicated the inappropriate movement. A comparison of correct and incorrect cues yields an estimate of an expectancy effect. The results indicated that both younger and older adults produced similar expectancy effects for the short delays. However, for the longest cue delays, the older adults produced a decreased expectancy effect, whereas the younger adults actually produced a slightly larger expectancy effect. In accordance with our arguments, Amrhein et al. argued on the basis of these results that older adults have difficulty maintaining an expectancy for the longer cue delays.

Why should one find an increased loss of prime information for the longest SOA in older adults? At a functional level, these results could be viewed as consistent with Craik's (1986) arguments that age-related deficits are magnified in tasks that provide very little environmental support. For example, age effects are smaller in recognition than in cued recall; in turn, age effects in cued recall are smaller than in free recall. Moreover, stimulus-driven priming effects in both semantic and episodic priming paradigms (e.g., Balota & Duchek, 1988, 1989) and in implicit priming paradigms (e.g., Light & Singh, 1987) have produced rather small, if any, age-related differences. With regard to our results, by providing the prime item in Experiment 2 throughout the prime–target SOA (i.e., environmental support for the direction of attention), we eliminated from the expectancy effect the age-related differences that occurred when subjects had to keep attention directed internally without direct stimulus support.

At a more mechanistic level, the loss of prime information in older adults may be related to recent arguments by Hasher and Zacks (1988) with regard to age-related changes in inhibitory processes. Those authors argued that the ability to inhibit irrelevant information may be reduced in older adults. If this is the case, it is possible that older adults are more likely to be distracted during the longest SOAs, under conditions in which the prime information is unavailable. This, of course, would dilute any expectancy effect. Younger adults may be able to keep extraneous stimuli inhibited during the longest SOAs even under conditions in which the prime is unavailable.

One might now ask why Burke et al. (1987) did not find an Age × Expectancy × SOA interaction in their lexical decision study. In their study, the primes were visually available for only 150 ms during either the 410-ms SOA or the 1,550-ms SOA. Thus the brief presentation of the primes across the two SOAs was similar to the procedures that we used in Experiments 1 and 3, in which there was clear evidence of interactive effects of age, expectancy, and SOA. There are two possibilities that may have led to the difference in results. First, Burke et al. used only two SOAs. It is possible that a third SOA would have produced the nonmonotonic function that we found in Experiments 1 and 3. In fact, if one examines only the short and long SOAs in Experiment 3 (see Table 9), one finds that the expectancy effects were quite similar for the younger and older adults. The major difference is that the younger adults' expectancy effect increased between the medium and long SOAs, whereas the older adults' expectancy effect decreased across the same SOAs. Thus without the intermediate SOA, one would have been unable to detect a difference in time course.

The second noteworthy difference between our experiments and Burke et al.'s (1987) experiment is that Burke et al. used an LDT. It is possible that in the LDT, older adults may use the target item to help retrieve prime information because of the postaccess checking process described in the introduction of this article. If this were the case, older adults may have been able to use the target as a retrieval cue for the prime at the longest SOAs, thereby producing a postaccess type of expectancy effect. Of course, the only way to fully discriminate between these possibilities is to conduct an LDT with the three SOAs used in either Experiment 1 or 3. If the inclusion of the third SOA is the crucial factor, one should expect the same pattern in pronunciation and in the LDT. If, however, differences in the pronunciation and the LDT are the crucial factor, one should expect to replicate Burke et al.'s results.

Finally, our results are relevant to recent arguments concerning general slowing accounts of age-related changes in priming effects. There are now two meta-analytic studies which have indicated that, overall, older adults produce slightly larger priming effects than do younger adults and that this can be nicely predicted from the fact that older adults also produce slower overall response latencies (Laver & Burke, 1990; Myerson, Ferraro, Hale, & Lima, in press). When effect size is considered as a function of overall response latency, any age-related differences disappear. In this light, it is noteworthy that a general slowing model could not account for the results of Experiments 1 and 3; that is, even though older adults' overall response latency was considerably slower than the younger adults, it is unclear how such a model could account for the systematic *increase* in the expectancy effect for the younger adults between the medium and long SOAs and the systematic *decrease* in the expectancy effect for the older adults across the same two SOAs. Thus the nonmonotonic influences of expectancy across SOAs for the older adults in this study are intriguing because these results do not conform to the predictions from a general slowing model of age-related differences in cognitive processing.

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