

Characteristics of Associative Learning in Younger and Older Adults: Evidence From an Episodic Priming Paradigm

Daniel H. Spieler and David A. Balota
Washington University

Two experiments investigated age differences in the encoding of associative information during a speeded naming task. In both experiments, semantically unrelated prime–target word pairs were presented 4 times, in either massed or spaced fashion, during the learning phase. An immediate or delayed test trial was presented following the fourth presentation. In Experiment 1, participants named both the primes and the targets. Younger and older adults showed similar benefits when naming targets that were part of a consistent prime–target pairing compared with targets presented with different primes at each presentation. In Experiment 2, participants named only the target word. Younger adults showed a benefit for consistently paired words, whereas older adults showed no benefit for consistently paired words. The results of the test trials showed a greater benefit for massed repeated words than for spaced repeated words at the immediate test and a reversed pattern at the delayed test. This spacing by test delay interaction was evident in response latency in Experiment 1 and in cued recall performance in Experiment 2.

One of the recurring interests in the area of learning and memory is the process of forming associations in memory. Beginning with simple paired associate learning before the turn of the century, this interest remains a central topic in studies of both episodic and semantic memory (Crowder, 1976). The present research examines the encoding of associative information within an episodic priming paradigm. *Episodic priming* refers to the benefit in speed and accuracy in making a response to a word when it is accompanied by another word with which it was paired earlier in the experiment (e.g., paired associates; McKoon & Ratcliff, 1979).

This article has two general goals. The first goal is to examine age differences in the encoding and retention of associative information in older adults as compared with younger adults. One suggestion regarding age differences in memory performance is that older adults are particularly deficient in their ability to create novel associative links in memory (MacKay & Burke, 1990). The present study examines this issue in some detail while avoiding some of the difficulties encountered in previous studies.

The second goal is to explore the effect of spacing of repetitions on episodic priming. One of the fundamental principles in learning is that spaced repetitions result in better memory

performance than massed repetitions (see Hintzman, 1976 for review). Moreover, there is an intriguing interaction between spacing and retention interval. The finding is that spaced repetitions produce better retention than massed repetitions in delayed memory tests, whereas this pattern is reversed in immediate memory tests (Peterson, Wampler, Kirkpatrick, & Saltzman, 1963). This study examines the effect of spacing on the encoding and retention of associative information in a relatively simple memory task that is different from those used in previous studies of the spacing effect and the interaction between spacing and test delay.

Aging and Associative Memory

The examination of age-related changes in associative memory has had a long history. On the basis of the observation that paired associate learning consistently produced large age differences, Gilbert (1941) suggested that older adults have particular difficulty in encoding associative information. More recently, MacKay and Burke (1990) proposed a theoretical framework that suggests that older adults suffer from a deficit in their ability to form novel associative connections in memory. Indeed, studies examining learning rates of associative information have consistently shown that older adults encode associative information more slowly than younger adults (Kausler & Puckett, 1980; Monge, 1971).

It is important to note that both Gilbert and MacKay and Burke suggested that the age-related differences in associative memory arise from a deficit in the *encoding* of novel associative information. The studies of paired associate learning in older adults have typically used cued recall performance as the memory measure. Burke and Light (1981) have suggested that age-related changes in retrieval processes may make substantial contributions to observed age differences in a number of different experimental paradigms. Thus, because encoding is not the only or perhaps the primary locus of these age-related deficits,

This work was supported by National Institute on Aging (NIA) Grant PO1 AG03991 and by NIA Training Grant AG00030. Portions of this research were presented at the 67th Annual Meeting of the Midwestern Psychological Association, Chicago, IL. We thank Zenzi Griffin, Darlene Howard, and Steve Kanne for many helpful comments on an earlier version of this manuscript.

Correspondence concerning this article should be addressed to Daniel H. Spieler or David A. Balota, Department of Psychology, Washington University, Box 1125, One Brookings Drive, St. Louis, Missouri 63130. Electronic mail may be sent via Internet to dspiel@artsci.wustl.edu or dbalota@artsci.wustl.edu.

these studies are equivocal on the issue of an encoding deficit in older adults. Fortunately, there have been recent studies that have attempted to minimize the contribution of retrieval processes to the observed age differences in associative memory.

One method that has been used to examine associative memory in younger and older adults is the episodic priming paradigm. As mentioned earlier, episodic priming refers to the increased speed or accuracy in the processing of a stimulus that is accompanied or preceded by an episodically related stimulus. Equivalent episodic priming for younger and older adults has been observed by Rabinowitz (1986), Howard, Heisey, and Shaw (1986), and Balota and Duchek (1989). Similar findings have also been reported for studies examining the reading time for word pairs (Light, LaVoie, & Kennison, 1995; Moscovitch, Winocur, & McLachlan, 1986) and the effects of context on word stem completion (Howard, Fry, & Brune, 1991).

However, these studies are not ideally suited to examining age differences in encoding because most of these studies have either attempted to equate episodic memory performance across younger and older adults (Balota & Duchek, 1989) or included only a single level of learning (Howard, Fry, & Brune, 1991; Rabinowitz, 1986). Of the two remaining studies, one (Howard, Heisey, & Shaw, 1986) reported that more study opportunities were required by older adults than younger adults before priming was observed. The present study will address this issue further by tracking the acquisition of associative information across multiple learning trials.

More recently, a series of studies reported by Light and colleagues (1995) examined associative priming in the speeded naming of repeated compound words and nonwords. In a series of experiments, Light et al. measured the naming latencies for items such as those formed from single-syllable words (e.g., "artmale" from "art" and "male") or from rearranged syllables from two-syllable words (e.g., "obnel" from "obsess" and "kenel"). These items were given numerous repetitions (up to 10) and, at the final repetition, the items could be repeated or changed by switching the second syllable with another repeated item (e.g., "artmale" changed to "artinch"). Light and colleagues suggested that the degree of associative learning is reflected in the cost observed in naming latency for the changed item compared with the unchanged item.

The methodology used by Light et al. appears to be analogous to the shift condition used frequently in the serial reaction time task (Nissen & Bullemer, 1987). In the serial reaction time task, individuals press a sequence of buttons in response to experimenter-provided cues. This sequence of button presses may repeat consistently across a number of blocks of trials. The degree to which individuals learn this sequence can be assessed by the extent to which their performance is disrupted when the consistent sequence is then changed to a random sequence. As in the serial reaction time task when a consistent sequence is changed, Light et al. observed a cost in naming latency for the changed item relative to the unchanged item.

Interestingly, Light et al. observed no difference in the magnitude of this cost in younger and older adults, which led the authors to the conclusion that there were no age differences in associative priming in this task. To the extent that one views this task as a verbal analog of a serial reaction time task, such a conclusion is not surprising given that studies have also re-

ported no age differences in learning in the serial reaction time task (Ferraro, Balota, & Connor, 1992; Howard & Howard, 1989, but see Harrington & Haaland, 1992).

However, there is reason to be hesitant in drawing a strong analogy between the serial reaction time task and the methodology used by Light et al. (see also Musen & Squire, 1993). Although there continues to be some debate about exactly what is learned in the serial reaction time task (see Poldrack & Cohen, 1995), clearly some of the learning is of transitions from one button press to the next in the sequence. One could view this as a creation of an association between two individual button presses. Note that there are no preexisting rules that govern how each button press or groups of button presses may be combined. In contrast, Light et al. referred to "associations" among phonological segments produced in the course of a single naming response. In such a situation, there are strong preexisting rules that govern how phonological segments may be combined, and this could compromise the interpretation of the observed effects. For example, Light et al. suggested that the cost incurred in the changed condition (e.g., "artmale" changed to "artinch"), relative to the repeated condition, reflects the disruption of a learned association between syllables ("art" and "male"). However, when the letter strings corresponding to each of the two syllables are re-paired with other syllables, syllable boundaries may shift. On the basis of linguistic principles of syllabification (Pulgram, 1970), shifting the letter string "art" in "artmale" to "artinch" results in the first syllable changing from "art" to "ar". Thus, in addition to breaking the "association", the actual units (syllables) entering into the association also change. The extent to which this might contribute to the measure of associative learning remains an empirical issue. However, in light of the possible complexities of this paradigm, the present set of experiments attempts to extend the Light et al. observations by examining age differences in the learning of associations *between* lexical items.

In addition, we will track the acquisition of this associative information under both massed and spaced presentations and at two different retention intervals. We shall now turn to these aspects of learning and retention.

Effects of Spacing and Test Delay

The *spacing effect* refers to the finding that when the to-be-remembered items are repeated in a list, spaced repeated items are generally remembered better than massed repeated items (see Crowder, 1976 for review). However, some studies have indicated that the spacing effect, although robust in most learning situations, can be modulated by the delay between the final repetition and the memory test (Balota, Duchek, & Paullin, 1989; Glenberg, 1976; Peterson, Wampler, Kirkpatrick, & Saltzman, 1963). When memory is tested shortly after the final repetition of an item, massed repeated items are actually remembered better than spaced repeated items. This pattern is, of course, strongly reversed if a delay is interposed between the final presentation and the memory test (e.g., spaced repeated items are remembered better than massed repeated items).

Previous studies investigating either the spacing effect or the interaction between spacing and test delay have typically used tasks such as cued recall (Balota, Duchek, & Paullin, 1989;

Glenberg, 1976; Peterson et al., 1963), recognition (see, for example, Greene, 1989), or implicit memory tasks such as word fragment completion or perceptual identification (Greene, 1990). In these studies, the dependent measure is probability correct for recognition and perceptual identification or probability of providing a target as a completion for word fragment completion. Each of these tasks demand explicit effortful retrieval either from episodic or semantic memory based on varying amounts of partial information available from the memory cue. However, it is unclear to what extent the engagement of such effortful retrieval operations are necessary for the observation of the spacing effect and the interaction of spacing and test delay. In this light, the second major goal of the first experiment was to examine the spacing by test delay interaction in a situation which minimized the need for individuals to engage in relatively effortful memory retrieval.

Experiment 1

In Experiment 1, words were presented as prime-target pairs in which both the primes and the targets required a simple naming response. There were three types of repetitions in the course of the experiment (see Table 1). One third of the trials consisted of repeated prime-target pairs (episodic repetition condition), one third were repeated targets paired with novel primes at each presentation (target repetition condition), and one third were repeated primes followed by novel targets at each presentation (prime repetition condition). Because of simple repetition effects, there should be a decrease in response latency to the target item across repetitions in both the episodic and target repetition conditions. More importantly, in addition to the repetition priming effect, there should also be a decrease in response latency in the episodic condition because of the episodic association between the prime and the target. Thus, the difference between the episodic and target repetition conditions is the primary measure of episodic priming. The prime repetition condition was included to ensure that individuals would not be able to use the presence of a repeated prime to predict the existence of a consistent prime-target relationship. The prime repetition condition also was included to assess the possibility that the repetition of the prime might confer some advantage to naming latency for the target.

There were four presentations that constituted the learning phase. These presentations were in either a massed or spaced fashion. The four presentations allowed the tracking of the ac-

quisition of an association between the prime and the target as reflected by the increase in episodic priming across the presentations. Thus, each presentation became a test for the preceding presentations. Moreover, from the point of view of the participant, the task consisted only of repeated naming trials with no explicit memory demands, thus minimizing encoding and retrieval strategies.

After the fourth presentation, the retention of the association that was created by the episodic repetitions was assessed by the manipulation of a delay between the fourth presentation and the fifth presentation. Thus, the fifth presentation was considered to be the test trial, although for the participants there was no distinction between learning and test trials. The previously mentioned interaction between spacing and test delay in the study would be reflected in greater episodic priming in the massed repetition condition compared with the spaced repetition condition at the immediate test and the reverse pattern for the delayed test.

There was one additional manipulation for the test trials. Because some of the episodic priming effect might be modulated by a build up of expectancy across repetitions, half of the test trials included a response-stimulus interval (RSI) that was twice the length of the RSI during the learning phase (1,500 ms vs. 750 ms). At the longer RSI, there may be a greater effect of expectancy because of the greater available time (Neely, 1977). Moreover, the build up of expectancy may be modulated by age, thus the effect of RSI may differ across age group (Balota, Black, & Cheney, 1992). For example, the 750 ms RSI may be sufficient for younger adults to generate some expectancy for the upcoming target word and the younger adults should be able to maintain this expectancy through the duration of the long 1,500 ms RSI. Thus, RSI might have little effect on the observed episodic priming for younger adults. On the other hand, the older adults may have difficulty in maintaining the expectancy at the longer delay and, hence, produce less episodic priming at the 1,500 ms compared with the 750 ms RSI.

Method

Participants

A total of 67 individuals participated. There were 33 young adults recruited from the student population at Washington University. The 34 older adults were recruited from the Washington University Aging and Development Subject pool. All participants were paid \$10 for their participation. One of the participants from the younger adult group ex-

Table 1
Example Conditions for Experiment 1

Presentation	Spaced trial no.	Massed trial no.	Repeated episodic	Repeated prime	Repeated target
1	12	12	Dog-chair	Dog-tent	Tree-chair
2	20	15	Dog-chair	Dog-wire	Car-chair
3	30	17	Dog-chair	Dog-tape	Bag-chair
4	42	20	Dog-chair	Dog-part	Knife-chair
Immediate test	45	23	Dog-chair	Dog-book	Can-chair
Delayed test	62	43	Dog-chair	Dog-book	Can-chair

Table 2
Description of Younger and Older Adult Participants in Experiment 1

Group	<i>N</i>	Gender (male/female)	Age	Education	WAIS Vocabulary
Younger	32	13/19	20.3 (2.5)	14.4 (1.6)	54.1 (7.4)
Older	32	11/21	71.8 (4.3)	14.0 (1.7)	55.5 (7.0)

Note. Standard deviations are in parentheses. WAIS = Wechsler Adult Intelligence Scale.

ceeded the 30-year-old criterion for young adults and was replaced. The data from two older adults also were replaced. One older adult failed to complete the experiment. The data from the other older adult were lost as a result of equipment failure. This left 32 younger adult participants and 32 older adult participants (see Table 2). The two age groups did not differ reliably in either education, $t(62) = 1.06$, or WAIS Vocabulary, $t(62) < 1$. All participants were native speakers of English.

Apparatus

An IBM compatible CompuAdd 386 computer was used to control the display of stimuli and to collect response latencies to the nearest millisecond. The stimuli were displayed on a NEC4G 14-inch color VGA monitor. The naming latency for each word was measured using a Gebrands Model G1341T voice-operated relay interfaced with the computer.

The words were presented individually, in 40-column mode on the computer screen. Words subtended 2-to-3 degrees of visual angle and were displayed in black on a white background.

Materials

There were 1,260 words used in the experiment. All words were one- and two-syllable English words with at least five occurrences per million (Kucera & Francis, 1967) ranging in length from three to six letters. The 1,260 words formed 630 semantically unrelated word pairs (as determined by D.S.). The words in each pair had approximately equal frequencies. As already noted, there were three conditions. The episodic condition consisted of intact word pairs that were presented five times within a block of trials. The prime repetition condition included a prime that was presented five times in a block of trials, each time with a novel target that appeared only once during the entire experiment. In the target repetition condition, the targets were repeated with a novel prime at each of the five presentations. Examples of the different conditions are presented in Table 1.

Across 32 participants, each word appeared equally often as the prime in both the prime repetition condition and the episodic condition and as the target in both the target repetition condition and the episodic condition. The novel words that were paired with the repeated items in the target and prime repetition conditions did not appear in the prime repetition, target repetition, or episodic conditions across the 32 participants.

Repeated words were presented five times within a block of trials. The first 4 presentations were considered to be the learning trials. The repetition of items during the learning trials could be either spaced or massed. The massed repetitions had 0–3 intervening items ($M = 1.7$), whereas the spaced repetitions had 8–12 ($M = 11.4$) intervening items. The fifth presentation of the items was the test trial. The test trials could be immediate (0–3 intervening trials) or delayed (18–23 intervening trials).

Because of the large number of cross-trial contingencies, a single list

structure was used for the presentation of the stimuli. Thus, each list position was assigned a spacing condition (massed or spaced) and a test delay (immediate or delayed) because these were the two conditions that involved cross-trial contingencies. For example, Trial 20 might be the first presentation of a spaced repetition immediate test condition. The assignment of these two conditions (spaced repetition, immediate test) required that the second presentation would occur between Trial 28 and Trial 32. Similarly, the test delay also constrained the position of the fifth presentation such that it would be between 27 and 39 trials after the first presentation. Thus, the list structure specified the spacing and test delay for each trial. However, the type of repetition (prime repetition, target repetition, episodic repetition) was not constrained by the list structure and, thus, was rotated across participants.

The list structure specified a single block of trials. There were five blocks of trials in the experiment, thus the list structure (the combination of spacing and test delay) was repeated five times for each participant although each block used a different set of stimuli. Each block provided two observations per cell, which yielded a total of 10 observations per cell per participant for test trials. The data for the learning trials collapsed across the test delay and test RSI yielded 40 observations per cell per participant for the learning phase.

Procedure

At the beginning of the experiment, participants were seated in front of the computer and the experimenter read the instructions for the experiment. Participants were told that they would be naming words that would appear on the computer screen. They were told to say each word aloud as quickly and as accurately as possible. On each trial, the following events occurred: (a) three plus signs (+ + +) appeared in the center of the screen for 500 ms, (b) a prime word appeared and remained on the screen until the participant responded, (c) the screen cleared for an RSI of 750 ms for the learning trials and either 750 ms or 1500 ms RSI for the test trials, (d) the target appeared and remained on the screen until the voice-operated relay was triggered, and (e) the screen cleared and the words "Left = OK, Right = Error" appeared on the screen. Participants were instructed to press the left button on a mouse if no error had occurred for either of the two preceding pronunciations making up that trial. If there had been an error, they were to press the right button. The participants were told that errors included stuttering before naming the word, vocalized pauses, coughing, or any other noises that may have triggered the voice key before they made their response. In addition, if the computer failed to detect their response, participants were told to repeat the word and then press the error button for that trial. If the voice key was triggered within 200 ms of the onset of a word, an anticipation was assumed to have occurred and the computer displayed a message in place of the mouse prompt screen. The message said "Remember, both speed and accuracy are important." The procedure of having the participants code their own responses has been used in both this laboratory (Balota & Duchek, 1988; Balota & Lorch, 1986) and other laboratories (see for example, Feustal, Shiffrin, & Salasoo, 1983) and evidence indicates that individuals are accurate in identifying errors. Once the participant pressed one of the mouse buttons, a 1500-ms intertrial interval was initiated followed by the next trial.

Each block consisted of 248 trials. Participants were given breaks at the end of each block of trials and were given feedback consisting of their mean naming latency and their number of errors. Participants were instructed to use this information to maintain or increase their speed for later blocks without increasing the errors.

Before starting the experimental trials, participants were given 16 practice trials during which the experimenter remained in the testing room to ensure that the participants understood the task. Because of the relative simplicity of this naming task, no participants required additional practice.

Design

The first 4 presentations constituted the learning phase of the experiment, whereas the fifth presentation was considered to be the test phase. For the learning phase, the design was a 2 (Young, Old) \times 2 (Massed vs. Spaced repetitions) \times 3 (Episodic vs. Target vs. Prime repetition conditions) \times 4 (Presentation) mixed-factor design, with Age as the only between-participants factor. For the test phase, the design was a 2 (Young vs. Old) \times 2 (Massed vs. Spaced repetitions) \times 2 (Immediate vs. Delayed Test) \times 3 (Episodic vs. Target vs. Prime repetition) \times 2 (RSI) mixed-factor design again with Age as the only between-participants factor. The primary dependent measure was naming latency for the target word.

Results

The naming latencies for trials that were marked as errors by the participants were excluded from all analyses. In addition, naming latencies that fell below 200 ms or below three standard deviations from the participant's mean for each block collapsing across condition were assumed to be either anticipations or voice-key errors and were not included in the analyses. Latencies falling beyond 2,000 ms or above three standard deviations from the mean were assumed to be lapses of attention and also were not included. In total, 3.0% of the responses in the younger adult group and 4.1% of the responses in the older adult group were eliminated from the analyses.

The first set of analyses are of the mean response latencies from the first 4 presentations constituting the learning phase. The second set of analyses are of data from the final presentations constituting the test trials.

Learning Phase

Overall analysis. Data from the mean response latencies to the target items for both age groups are shown in Figure 1. Inspection of these data revealed that (a) older adults were overall slower than younger adults, (b) mean response latencies for the target items decreased as a function of repetition for the target and episodic repetition conditions compared with the prime repetition condition, (c) the effect of repetition appeared to be larger for the episodic than for the target repetition condition, and (d) the pattern of priming in the target and episodic repetition conditions appeared to be very similar for younger and older adults.

These observations were supported by a 2 (Age) \times 2 (Spacing) \times 3 (Repetition type) \times 4 (Presentation) mixed-factor analysis of variance (ANOVA). This analysis revealed significant main effects for all factors: Age, $F(1, 62) = 64.98$, $MSE = 104608$, $p < .001$; Spacing, $F(1, 62) = 8.74$, $MSE = 405$, $p < .005$; Repetition type, $F(2, 124) = 166.74$, $MSE = 435$, $p < .001$; and Presentation, $F(3, 180) = 96.66$, $MSE = 207$, $p < .001$. There was also a significant Spacing \times Repetition Type interaction, $F(2, 120) = 130.78$, $MSE = 170$, $p < .001$, indicating that target and episodic conditions were generally faster in the massed than in the spaced conditions, but spacing had little effect on the Prime repetition condition. Moreover, a significant Spacing \times Presentation interaction, $F(3, 186) = 19.45$, $MSE = 121$, $p < .001$, indicated that massed repeated items generally decreased in latency to a greater extent than spaced repeated items. There was also a significant Spacing \times Repetition Type \times Presentation

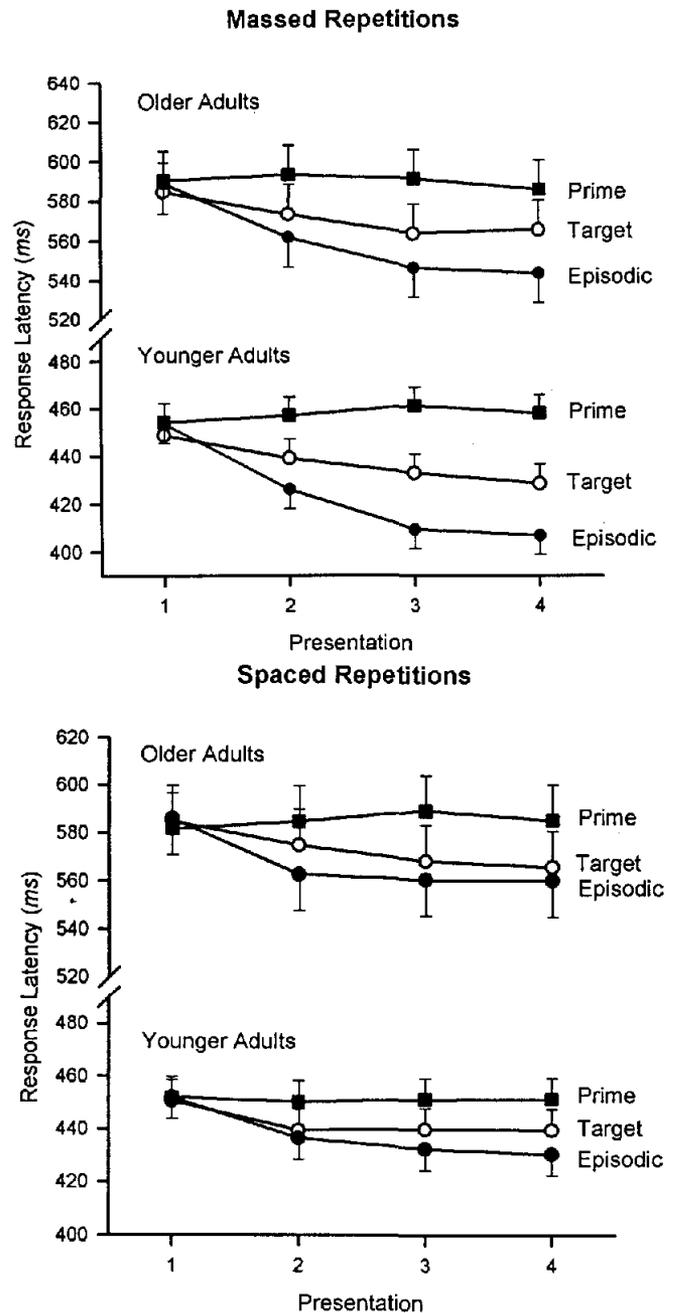


Figure 1. Mean naming latency for target words as a function of age, repetition condition, and presentation for Experiment 1. Top panel contains data from the Massed Repetition condition; bottom panel contains data for the Spaced Repetition condition. Error bars represent one standard error.

interaction, $F(6, 372) = 9.81$, $MSE = 98$, $p < .001$, reflecting the greater episodic priming in the massed than in the spaced repetition condition.

The only interaction involving Age to reach significance was the four-way interaction, $F(6, 372) = 3.36$, $MSE = 98$, $p < .005$. This interaction was due to age differences in the prime repeti-

tion condition. When the prime, target, and episodic repetition conditions were analyzed in three separate 2 (Age) \times 2 (Spacing) \times 4 (Presentation) mixed-factor ANOVAs, the only Age interaction to reach significance was the Age \times Spacing \times Presentation interaction for the prime repetition condition, $F(3, 186) = 3.10$, $MSE = 114$, $p < .05$. It appears that there is some tendency for response latency to increase slightly in the prime repetition condition for both age groups, but this tendency is greater in the older adults than in the younger adults. Because this condition was included so that individuals could not use the presence of a repeated prime to predict a consistent prime-target pairing and the results from this condition are not theoretically motivated, we believe this tendency in the data to be spurious. However, this pattern does not suggest any benefit for the naming of a target following a repeated prime word. Because the relative difference between the target and episodic conditions serves as the measure of episodic priming, we shall now turn to the analyses of the target and episodic repetition conditions.

Episodic priming analysis. The mean naming latencies were analyzed by a 2 (Age) \times 2 (Spacing) \times 2 (Repetition type) \times 4 (Presentation) mixed-factor ANOVA. As expected, there were significant main effects of Age, Spacing, Repetition type, and Presentation ($F_s > 30$, $p_s < .001$). In addition, the build up of episodic priming was greater for the massed repetitions than for the spaced repetitions as indicated by a significant Spacing \times Repetition type \times Presentation interaction, $F(3, 186) = 12.24$, $MSE = 93$, $p < .001$. Moreover, none of the interactions involving Age and Repetition type approached significance (all $p_s > .10$). Thus, these analyses revealed little in the way of age differences in the build up of episodic priming across the first 4 presentations in either the spaced or massed conditions.¹

The next analyses are of the fifth and final presentation. The final presentation could be presented either soon after the fourth presentation (0 to 3 intervening trials) or after some delay (18 to 22 intervening trials). These analyses allow us to examine the interaction of spacing and test delay in episodic priming.

Test Trials

The mean response latencies on the test trials are shown in Table 3. Note that the episodic priming effect was greater overall for massed than for spaced repetitions and that the priming effect decreased as a function of test delay. Moreover, the size of the priming effect was very similar across younger and older adults. One must remember that the pattern for the spacing by test delay interaction is that massed repeated items show better memory performance for immediate tests compared to spaced repeated items and that this pattern is reversed when a delay is interposed between the final presentation and the test (e.g., Peterson, Wampler, Kirkpatrick, & Saltzman, 1963). Inspection of the priming effects reported in Table 3 indicates that both younger and older adults clearly show more priming at the immediate test for massed than for spaced repetitions and the reversed pattern at the delayed test, and it appears that Age does not modulate this interaction.

The results of a 2 (Age) \times 2 (Spacing) \times 2 (Delay) \times 2 (Repetition type) \times 2 (RSI) mixed-factor ANOVA supported these observations. This analysis revealed main effects of Age, $F(1, 62) = 86.09$, $MSE = 23739$, $p < .001$; Spacing, $F(1, 62) =$

Table 3
Mean Naming Latencies for Test Trials as a
Function of Group and Condition

Condition	Delay	
	Immediate	Delayed
Younger adults		
Massed repetitions		
Prime	467 (45)	460 (50)
Target	435 (42)	442 (42)
Episodic	400 (44)	439 (42)
Priming effect	35	3
Spaced repetitions		
Prime	471 (48)	464 (46)
Target	436 (47)	448 (42)
Episodic	413 (44)	435 (45)
Episodic priming effect	23	13
Older adults		
Massed repetitions		
Prime	599 (76)	601 (98)
Target	559 (63)	565 (65)
Episodic	529 (64)	561 (63)
Priming effect	30	4
Spaced repetitions		
Prime	603 (83)	594 (87)
Target	562 (71)	577 (78)
Episodic	538 (73)	562 (68)
Priming effect	24	15

Note. Standard deviations are in parentheses.

10.82, $MSE = 306$, $p < .005$; Delay, $F(1, 62) = 130.2$, $MSE = 390$, $p < .001$; and Repetition type, $F(1, 62) = 73.13$, $MSE = 595$, $p < .001$. In addition, there was greater episodic priming for the immediate test than for the delayed test, $F(1, 62) = 25.32$, $MSE = 478$, $p < .001$. There was no main effect of RSI and no interactions involving RSI ($F_s < 1$). This suggests either that attentional expectancies did not play much of a role in the pattern of priming in this experiment or that a 750-ms RSI allowed sufficient time for the expectancies to be brought to bear

¹ Recently, there has been some discussion about the presence of associative learning after a single presentation (e.g., Musen & Squire, 1993). To address this issue, we analyzed the second presentation naming latency data for Experiment 1 in a 2 (Age) \times 2 (Spacing) \times 2 (Repetition Type, Target vs. Episodic) mixed-factor ANOVA. This analysis revealed a significant Repetition Type main effect reflecting the 10-ms advantage for the Episodic repetition compared with the Target repetition condition, $F(1, 62) = 41.13$, $p < .001$, $MSE = 153$. In addition, there was a marginally significant Age \times Spacing \times Repetition Type interaction, $F(1, 62) = 3.89$, $MSE = 116$, $p = .053$. This reflected the greater episodic priming shown by the younger adults in the massed condition compared with the spaced condition (12 vs. 3 ms), whereas older adults showed very similar priming for both the massed and spaced conditions (12 vs. 11 ms). This interaction appeared to be due to smaller repetition effects on the second presentation in older adults. In an identical analysis conducted using the prime rather than the target repetition condition, this interaction was not significant, $F(1, 62) = 1.82$, $MSE = 116$, $p > .10$. Thus, in this experiment, there was evidence for associative priming after a single presentation.

by both the younger and older adults. Subsequent analyses did not include this factor.

Within the context of the present study, the predicted spacing by test delay interaction in episodic priming should be reflected by the Spacing \times Repetition Type \times Delay interaction. Indeed, this interaction was significant, $F(1, 62) = 11.74$, $MSE = 270$, $p < .001$. There was marginally greater episodic priming at the immediate test for massed repetitions than for spaced, Spacing \times Repetition Type interaction, $F(1, 62) = 3.31$, $MSE = 405$, $p = .07$, whereas at the delayed test, there was greater episodic priming for the spaced repetitions than for the massed, Spacing \times Repetition Type interaction, $F(1, 62) = 10.63$, $MSE = 178$, $p < .005$. None of the interactions involving Age approached significance ($ps > .10$).

Discussion

The results from the test trials showed the classic spacing by test delay interaction. Thus, the experiment suggests that one can obtain this interaction in situations in which response latencies and not response probabilities are the primary dependent measure. Indeed, these results are the first that we are aware of that demonstrate this interaction using response time as the primary dependent measure.

It is important to note that Greene (1989, 1990) suggested that for cued memory tests, including recognition tests and implicit memory tasks, the benefit for spaced repeated items at a delayed memory test may arise from a rehearsal strategy that individuals adopt only under intentional learning conditions. This strategy results in greater rehearsal being allocated for spaced repeated items than for massed. Given the speeded naming task used in this experiment, it is unlikely that individuals engaged in any consistent rehearsal of the repeated words. Thus, the observation of a spacing effect at the delayed test in the present study suggests that rehearsal strategies are not necessary for the observation of a benefit for spaced compared with massed repeated items.

These data do not offer strong support for the notion of a deficit in the encoding of associative information in older adults. Rather, these results suggest that at least some of the deficits observed in previous studies of paired associate learning may have arisen from age differences in effortful retrieval processes and that when care is taken to minimize the retrieval requirements, the build up of an episodic trace may be quite comparable across age groups.

Before rejecting the notion of an age-related breakdown in the encoding of associative information, it is important to entertain the possibility that learning in the present task could occur at multiple levels in the processing system. At a higher level, an episodic memory trace is likely to be formed through the repeated cooccurrence of words. However, episodic priming in this study could also include some contribution from output or motor forms of associative priming. For example, the episodic repetition condition required the repeated naming of consistently paired prime-target word pairs. To the extent that some form of association could be formed between the motor-articulatory program for naming the prime and that for naming the target, such increased fluency of executing this motor program could contribute to the measure of episodic priming.

The formation of associations among individual actions, in this case word naming, might be similar to the associative learning in the serial reaction time (SRT) task (Nissen and Bullemer, 1987) in which individuals become increasingly fluent in the production of a repeating sequence of key presses. It is now apparent that learning in the SRT task occurs at a number of different levels (cf. Poldrack & Cohen, 1995; Reed & Johnson, 1994; Willingham, Nissen, & Bullemer, 1989). However, it does appear that a component of learning in this task is motoric in nature (Willingham et al., 1989). More important, Howard and Howard (1989; see also Ferraro, Balota, & Connor, 1992) have shown that the learning in the SRT task is relatively spared in older adults. Thus, if Experiment 1 allows the contribution of a form of motor learning that is implicated in the SRT task, then this might be consistent with the lack of age differences in episodic priming in this study.

In Experiment 2, an attempt was made to minimize the contribution of such procedural learning to the measure of episodic priming. This was done by requiring naming responses only for the target word. By removing the requirement that individuals make an overt response to the prime, the contribution of procedural or articulatory learning should be minimized. By doing so, one should obtain a clearer picture of age differences in what can be more appropriately termed episodic priming.

However, the increased fluency in executing the articulation of the prime and the target is also of some interest. It seems possible that repetition, in addition to strengthening an association between the articulatory plan for the prime and the target, might also increase the fluency of the actual articulation of an individual word. This would result in the shortening of the production duration for the repeated word. A few studies have shown that the production duration of words may be affected by factors such as word frequency, semantic relatedness, and given-new information (Balota & Abrams, 1995; Balota, Boland, & Shields, 1989; Fisher & Tokura, 1995; Fowler & Housum, 1987; Shields & Balota, 1991). Thus, another purpose of the present study was to address two issues pertaining to the effect of repetition and episodic priming on single word production durations. The first issue is the extent to which the modulation of production durations might be affected by repetition and episodic priming. Simple repetition would be expected to modulate the production durations of words if articulatory codes in language production are anything like other motor sequences and, hence, become more fluent with repetition. The prediction for episodic priming is less clear. The finding of semantic effects on production durations of isolated words appears to require the concurrent presence of the semantically related prime (Balota, Boland, & Shields, 1989). Assuming some similarity between semantic priming and episodic priming, the fact that the prime and target are presented in sequence with no overlap in the present experiment suggests that there should be no effect of episodic priming on production durations. The second issue is to what extent might such changes in production durations resulting from repetition and episodic priming differ in younger and older adults. On the basis of the results of Howard and Howard (1989), which seem to suggest that a form of procedural or motor learning is largely intact in older adults, one might predict that the production durations of younger and

older adults will be affected equally by a factor such as repetition.

Experiment 2

The purpose of Experiment 2 was to reduce the contribution of a procedural form of associative priming to the measure of episodic priming. The experiment required participants to provide a naming response to the target word only. To encourage the processing of the prime and to examine the explicit accessibility of the prime–target pairing, the test trials were changed to cued recall trials in which the prime was presented with three question marks and the task was to produce the associated target word.² Clearly, the expectation is that older adults generally will be less able than younger adults to retrieve the target word on the cued recall trials, although the nature of the spacing by test delay interaction is also of interest. What is of particular importance is the extent of age-related differences in priming during the learning trials once the possibility of motor associative priming was eliminated.

Experiment 2 also examined a form of motor learning by measuring the duration of the articulation of the naming response. If older adults were relying on more output–motor learning for the observed priming effect in Experiment 1, and such motor learning is largely spared by the aging process, one might predict (a) age differences in episodic priming when no naming of the prime is required, and (b) no age differences in the modulation of response output (production durations) as a function of simple target repetition.

Method

Participants

There were a total of 64 participants. Thirty-two young adults were recruited from the undergraduate student population at Washington University, and the 32 older adults were recruited from the Washington University Aging and Development Subject pool. None of these individuals participated in Experiment 1. All participants were paid \$10 for their participation. The characteristics of the participants in this study are reported in Table 4. The two age groups did not differ reliably in either education, $t(62) = 1.04$, or WAIS Vocabulary, $t(62) < 1$.

Apparatus

Apparatus was the same as in Experiment 1.

Materials

Materials were the same as in Experiment 1 except that there were four blocks of trials instead of five blocks as in Experiment 1. The re-

duction in length was an attempt to reduce the length of an experimental task that was more demanding than the task in Experiment 1 because of the addition of the cued recall trials. The length and structure of individual blocks were identical to those in Experiment 1.

The rotation of items through episodic, target, and prime repetition conditions was accomplished in the same manner as in Experiment 1. As in Experiment 1, all repeated items rotated through each condition across 32 participants.

Procedure

At the beginning of the experiment, participants were seated at the computer while the experimenter read the instructions for the experiment. On each learning trial, the following events occurred: (a) three plus signs (+ + +) appeared in the center of the screen for 500 ms, (b) a prime word appeared and remained on the screen for 750 ms, (c) the screen cleared for 50 ms and the target appeared and remained on the screen until the participant responded, and (d) the screen cleared and a 1500-ms intertrial interval was initiated. Participants were told to read the first word silently and then read the second word aloud as quickly and as accurately as possible. Participants were encouraged to attend to the prime–target pairing because a few times in every block of trials they would receive a test in which they would be given the prime word and asked to supply the word that had been paired with it. For the cued recall trials, after the presentation of the fixation, the prime word followed by a dash and three question marks appeared at the center of the screen. This remained on the screen until the voice key was triggered by the participant's response. Participants were instructed to say their response aloud as soon as they retrieved the correct word or, if after a few seconds, they were unable to come up with a response, they were told to say the word "No" aloud. After the voice key was triggered, the screen cleared and the computer displayed the correct response. Participants were asked to press the left button on a mouse if the word displayed on the computer screen matched exactly the word that they had just said, otherwise they were told to press the right button on the mouse. Once a button press was made, the 1500-ms intertrial interval was initiated, followed by the next trial. Participants' cued recall responses were also taped to ensure the accuracy of the coding for cued recall trials. A comparison of recall accuracy, made on the basis of participants' reports and tapes of 10 randomly selected younger adults and 10 randomly selected older adults, revealed incorrect coding for 4% of the responses for younger adults and 2% for the older adults. None of these individuals revealed any consistent tendency either to underestimate or overestimate their recall accuracy.

Design

The learning phase consisted of the first four presentations. For the learning phase, the design was a 2 (Young vs. Old) \times 2 (Massed vs. Spaced repetitions) \times 3 (Episodic vs. Target vs. Prime repetition conditions) \times 4 (Presentation) mixed-factor design with Age as the only between-participants factor. The dependent measures were naming latency and naming durations for the target word. There were 32 observations per cell per participant for the learning phase. The design for the test trials was a 2 (Young vs. Old) \times 2 (Massed vs. Spaced repetitions) \times 2 (Immediate vs. Delayed Test) mixed-factor design with Age as the only between-participant factor. For the test trials, the dependent measure

Table 4

Description of Younger and Older Adult Participants in Experiment 2

Group	N	Gender (male/female)	Age	Education	WAIS Vocabulary
Younger	32	14/18	21.9 (4.2)	15.0 (2.2)	53.8 (5.9)
Older	32	13/19	72.4 (5.1)	14.3 (2.7)	55.1 (6.9)

Note. Standard deviations are in parentheses. WAIS = Wechsler Adult Intelligence Scale.

² An earlier version of this experiment was conducted without cued recall trials. Thirty-two younger adults participated, and these participants did not show any evidence of episodic priming. This study indicated that explicit processing of the prime may be necessary for the development of episodic priming.

was the probability of correct recall. There were 16 observations per cell per participant for the cued recall trials.

Results

The screening procedure for response latencies was the same as for Experiment 1. This screening procedure eliminated 1.8% of the responses in the younger adult group and 3.1% of the responses in the older adult group.

Learning Phase

Overall analysis. Data from the mean naming latencies to the target items for both age groups are displayed in Figure 2. Inspection of these data revealed that (a) older adults were overall slower than younger adults, (b) mean response latencies decreased as a function of repetition for the target and episodic repetition conditions compared with the prime repetition condition, and (c) there appeared to be a larger effect of repetition for the episodic than for the target repetition condition for younger adults but little difference between the episodic and target repetition conditions for the older adults.

To support these observations, the mean naming latencies for each participant were analyzed in a 2 (Age) \times 2 (Spacing) \times 3 (Repetition type) \times 4 (Presentation) mixed-factor ANOVA. As expected, this analysis resulted in significant main effects of Age, $F(1, 62) = 22.58$, $MSE = 290969$, $p < .001$, Repetition type, $F(2, 124) = 60.90$, $MSE = 1094$, $p < .001$, and Presentation, $F(3, 186) = 17.25$, $MSE = 528$, $p < .001$. More important, there was a significant Age \times Repetition type \times Presentation interaction, $F(6, 372) = 3.33$, $MSE = 560$, $p < .005$.

Episodic priming analysis. Mean naming latencies for the target and episodic repetition conditions were analyzed in a 2 (Age) \times 2 (Spacing) \times 2 (Repetition type) \times 4 (Presentation) mixed factor ANOVA. This analysis revealed the expected Age \times Repetition Type \times Presentation interaction, $F(3, 186) = 7.78$, $MSE = 626$, $p < .001$. To explore further the differences in priming across these two age groups, we examined the episodic and target repetition conditions separately for younger and older adults. For younger adults, this analysis revealed significant main effects of Spacing, Repetition type, and Presentation, (F 's > 13 , p 's $< .01$). Moreover, there was a significant Spacing \times Repetition Type \times Presentation interaction, $F(3, 93) = 4.84$, $MSE = 220$, $p < .005$. The younger adults showed episodic priming in both spacing conditions although the effect was greater for massed (43 ms) than for spaced (20 ms) by the fourth presentation. In contrast, the analysis of naming latencies for older adults revealed only a significant main effect of Presentation, $F(3, 93) = 4.18$, $MSE = 1070$, $p < .01$. None of the other main effects or interactions approached significance (F 's < 1.2 , p 's $> .10$). Episodic priming, as reflected by the difference between target repetition and episodic conditions, was 2 ms for massed repetitions and 0 ms for spaced repetitions. Thus, older adults showed no episodic priming across the four presentations constituting the learning phase of the study in either the massed or spaced repetition conditions.

In addition to the analyses of the response latencies, we also conducted an analysis of the response durations. The naming durations were initially screened using a minimum cutoff of 50

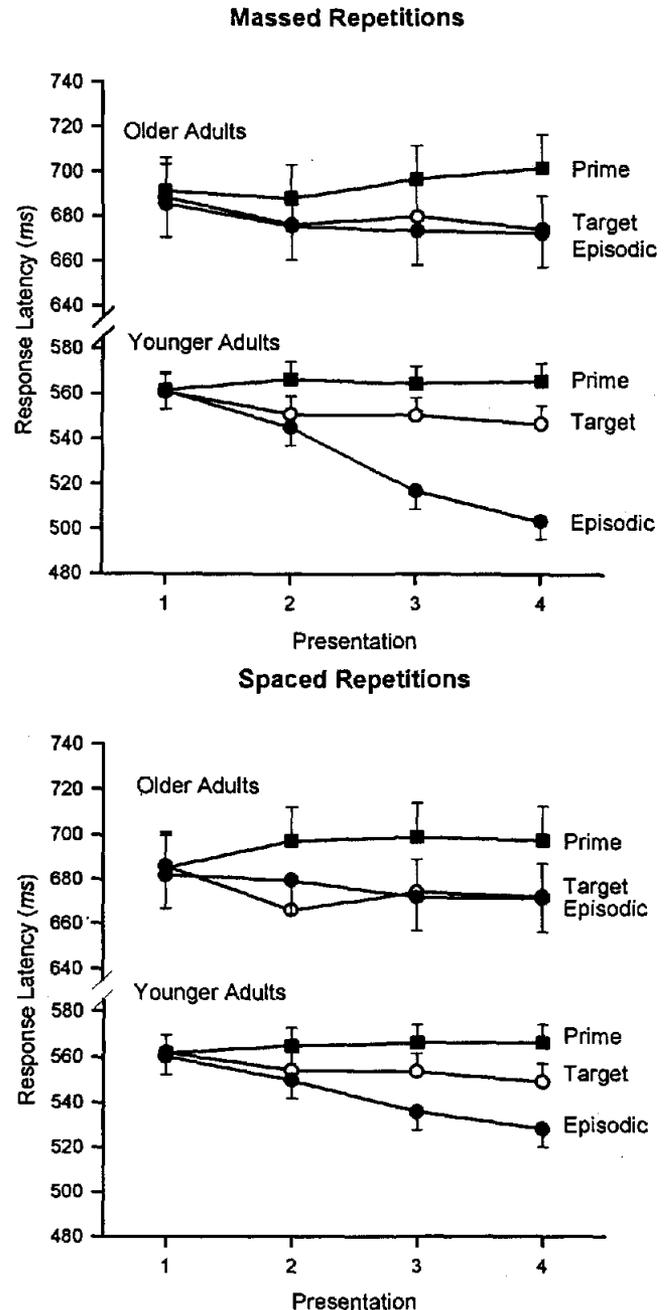


Figure 2. Mean naming latency for target words as a function of age, repetition condition, and presentation for Experiment 2. Top panel contains data from the Massed Repetition condition; bottom panel contains data for the Spaced Repetition condition. Error bars represent one standard error.

ms. This was done to eliminate those trials that were most likely to be stutters or trials on which the voice key incorrectly identified a midword pause as the end of the response. Subsequently, a mean and standard deviation was computed for each participant collapsing across all conditions, and those observations that fell above or below 2.5 standard deviations from this mean

were identified as outliers and eliminated from all duration analyses. These screening criteria eliminated 2% of all observations for the younger adults and 4.6% of all observations for the older adults.

The mean naming durations are reported in Figure 3. Note that because there were different target words in the prime repetition condition, these naming durations were not included in the analysis. There are two noteworthy aspects of these data. First, older adults generally have longer naming durations than do younger adults. Second, the type of repetition (target or episodic) does not appear to affect the naming durations. These data were analyzed in a 2 (Age) \times 2 (Spacing) \times 2 (Repetition type) \times 4 (Presentation) mixed-factor ANOVA. This analysis indicated that older adults generally had longer naming durations than younger adults, $F(1, 62) = 12.09$, $MSE = 87248$, $p < .001$. This Age main effect replicates previous reports of longer naming durations in older adults compared with younger adults (Balota & Duchek, 1988; Multhaup, Balota, & Cowan, 1996). This analysis also revealed a significant repetition effect in durations, $F(3, 186) = 9.17$, $MSE = 179$, $p < .001$. Indeed, most surprising is the finding of significant repetition effect in naming durations in the spaced condition in spite of the presence of an average of 10 intervening items, $F(3, 186) = 6.06$, $MSE = 149$, $p < .001$. Neither the main effect of Spacing nor Repetition type approached significance ($F_s < 1$). None of the interactions reached significance. Thus, overall it appears that younger and older adults modulate equally the duration of their naming responses as a function of repetition.

Cued Recall Trials

The data from the cued recall trials are displayed in Figure 4. As expected, younger adults were generally able to recall more than older adults. Also, as shown in Figure 4, recall probability decreases with test delay and the effect of delay is generally

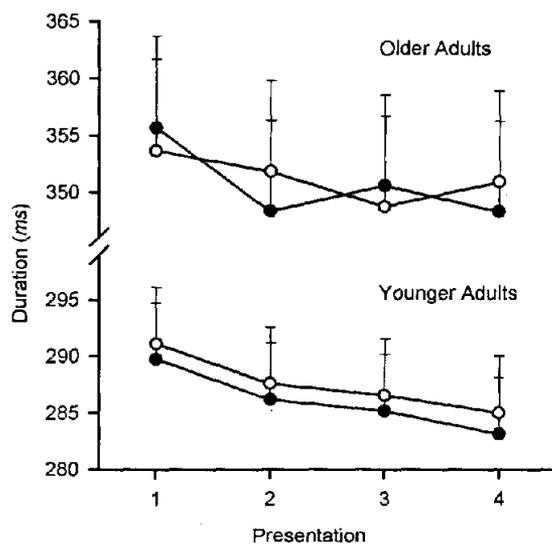


Figure 3. Mean naming durations as a function of age and presentation. Error bars represent one standard error.

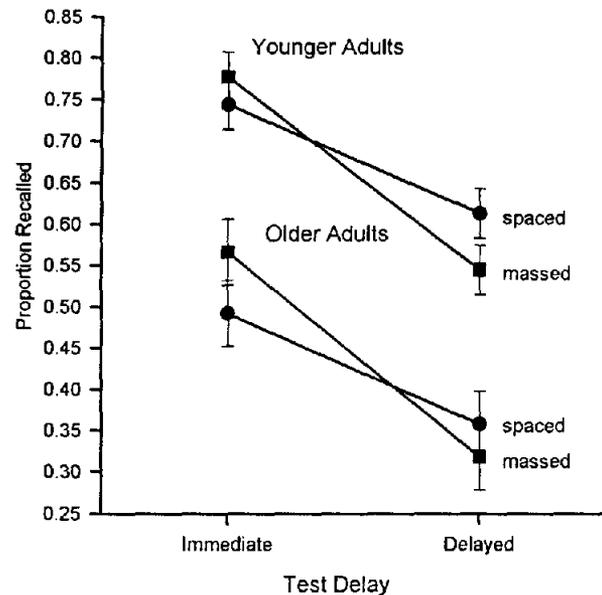


Figure 4. Mean cued recall proportion as a function of age, repetition spacing, and test delay. Error bars represent one standard error.

greater for massed repeated items than for spaced repeated items. Finally, both age groups exhibit the expected spacing by test delay interaction and there do not appear to be any differences between age groups in the nature of this interaction.

The above observations were supported by a 2 (Age) \times 2 (Spacing) \times 2 (Test Delay) mixed-factor ANOVA. This analysis revealed significant main effects of Age and Test Delay ($p_s < .001$). More interestingly, there was the expected Spacing \times Delay interaction, $F(1, 62) = 14.43$, $MSE = .0128$, $p < .001$. There were no significant interactions with the Age factor (all $F_s < 1$) indicating that the interaction was very similar across age group. This replicates the finding of age invariance in the spacing by test delay interaction reported in the cued recall data of Balota, Duchek, and Paullin (1989).

Discussion

With regard to the learning trials, there are three points to note. First, younger adults exhibited a significant buildup of episodic priming across repetitions, whereas older adults showed no hint of episodic priming across the first 4 presentations. Thus, the elimination of the possibility of an output-motor form of associative learning eliminated episodic priming for the older adults. Second, if one examines the manner in which individuals modulate the characteristics of their responses, one finds that younger and older adults shorten their naming durations as a function of repetition to the same extent. However, the effect on naming durations occurred equivalently in the target and the episodic repetition conditions. Thus, episodic information had no discernible influence on naming durations for either age group. Third, the results from the cued recall trials showed the crossover interaction between spacing and test delay as has been found previously and this interaction is equivalent across younger and older adults.

Comparison of Experiments 1 and 2

The results of the two experiments suggest that the locus of learning in younger and older adults in Experiment 1 differed from that in Experiment 2. Under circumstances in which output processes may contribute to episodic priming, younger and older adults showed similar amounts of episodic priming compared with situations in which the contribution of output processes is minimized. Thus, age differences were small in Experiment 1, in which both primes and targets were named; whereas there were large age differences in Experiment 2, in which only the targets were named.

Of course, one must always be cautious of cross-experiment comparisons without direct statistical support. Thus, an analysis was conducted on naming latencies for the learning trials in which Experiment was included as a between-participant factor. The mean naming latencies for the episodic and target repetition conditions were analyzed in a 2 (Experiment) \times 2 (Age) \times 2 (Spacing) \times 2 (Repetition Type) \times 4 (Presentation) mixed-factor ANOVA. The results of this ANOVA yielded a significant Experiment \times Age \times Repetition Type \times Presentation interaction, $F(3, 372) = 3.84$, $MSE = 337$, $p < .01$, indicating that age differences in episodic priming were larger in Experiment 2 than in Experiment 1.

General Discussion

The purpose of the present experiments was to examine the encoding of associative information in younger and older adults and to examine the interaction of spacing and retention interval in an episodic priming task. We shall first turn to the implication that these data have for age-related changes in the processing of associative information.

Age Differences in Episodic Priming

The results of the analyses of the overall response latencies from Experiment 1 revealed little evidence for age differences in the encoding of associative information. However, because individuals were required to name both the primes and the targets and response latency was measured for the target word, there was some potential for a more motor form of associative learning. Thus, Experiment 2 eliminated the contribution of output processes to episodic priming by requiring naming responses to the target only. The results of this experiment indicated that, although younger adults still produced episodic priming, there was no evidence of episodic priming for the older adults. Thus, these results provide support for the notion of a deficit in the encoding of associative information in older adults.

The likelihood that age differences should be attenuated in circumstances in which individuals may use motoric forms of associative learning could be viewed as being consistent with the findings of Howard and Howard (1989). They examined age differences in the SRT task developed by Nissen and Bullemer (1987) and showed that younger and older adults benefit, to an equivalent extent, from the consistent output of a particular motor sequence in the SRT task (see also Ferraro, Balota, & Connor, 1992).

However, it is unlikely that the episodic priming effect ob-

served in Experiment 1 was entirely without any episodic contribution. Indeed, there does appear to be some evidence for age differences in episodic priming in Experiment 1. One of the most salient features of the data in both experiments is the sizable difference in overall speed between younger and older adults. Some researchers have suggested that conclusions about effect sizes need to take into account the extent to which groups differ in overall speed of processing (see for example, Cerella, 1991; Myerson, Hale, Wagstaff, Poon, & Smith, 1990). Specifically, the results of a number of meta-analyses suggest that effect sizes are generally larger in groups with slower processing speeds. However, the results of both experiments show that older adults are generally showing either equivalent or smaller priming effects than are younger adults.

Viewed from a generalized slowing perspective, the slightly smaller priming effect for older adults in Experiment 1 might suggest a deficit in episodic priming that was accentuated in Experiment 2. The difficulty in situations such as this lies in arriving at an appropriate method for correcting for group differences in speed. One approach is to plot the mean response latencies of older adults against those of younger adults in Brinley plots (Cerella, 1991; Myerson et al., 1990; Salthouse & Somberg, 1982). Such plots typically sample a broad range of response latencies from a number of tasks in contrast with the present study with a comparatively small number of data points and a limited range of response latencies. An alternative approach is to make some assumption of how effect sizes change as a function of changes in overall response latency. Although there is little consensus on how this should be done, one method that has been used assumes that effect sizes scale up as a constant proportion of overall response latency (e.g., see Burke, White, & Diaz, 1987; Dulaney & Rogers, 1994; Hartley, 1993; Spieler, Balota, & Faust, 1996). On the basis of this assumption, the data from Experiment 1 were reanalyzed by converting each participant's mean naming latencies for the target and episodic repetition conditions to ratio scores by dividing the mean for each condition by the participant's grand mean collapsing across Prime, Target, and Episodic repetition conditions.³ These ratios were then analyzed in a 2 (Age) \times 2 (Spacing) \times 2 (Repetition Type) \times 4 (Presentation) mixed-factor ANOVA. Limiting our attention to the issue of age differences, there was a significant Age \times Repetition Type \times Presentation interaction, $F(3, 186) = 3.33$, $MSE = .0004$, $p < .05$, reflecting the proportionately larger episodic priming effect in younger adults compared with older adults in Experiment 1. These results, in conjunction with the results from Experiment 2, converge on the notion that older adults are impaired relative to younger adults in the encoding of associative information.

It is important to note that there are differences between the experiments beyond whether or not the prime word was named. First, there was a greater degree of self-pacing in Experiment 1 because the prime and the target words remained on the screen until the participant named the word. There is at least one study

³ The denominator for the ratio analysis was each individual's mean response latency across all conditions. This was chosen to obtain a more accurate estimate of each individual's speed of processing. Analyses on ratios using the target repetition condition as the denominator yielded qualitatively identical results.

(Howard, Heisey, & Shaw, 1986) that suggests that age differences may be attenuated in situations in which stimulus presentation is self-paced although this study used a more traditional list learning task. Second, the finding of attenuated age differences in Experiment 1 may be due to the slower rate of presentation for older adults compared with younger adults. Specifically, the removal of the requirement that individuals name the prime in Experiment 2 results in an average time between the prime and the target that is shorter than in Experiment 1. It may be the case that the older adults benefited from this increased study time in Experiment 1. An indirect way of addressing this is to examine the pattern of priming for fast and slow participants. Individuals with fast naming latencies had a higher rate of stimuli presentation in Experiment 1, whereas the slower individuals had a lower rate. If the rate of presentation is crucial, one might predict that the slower individuals in each group should show greater episodic priming effects. In an attempt to address the issue of learning time, albeit indirectly, we divided each age group into a fast and a slow subgroup and included Speed as a factor in an ANOVA. To the extent that speed of processing influences episodic priming, this should be reflected by interactions involving the Speed and Repetition Type factors. However, in an ANOVA conducted on the naming latencies for the learning trials in Experiments 1, which included Speed as a factor, neither the Speed \times Repetition Type interaction nor the Age \times Speed \times Repetition Type interactions were reliable ($F_s < 2$, $p_s > .15$). The priming effects for the fast responders was not significantly different from that of the slower responders (14 ms vs. 17 ms, respectively).

The converse argument may be made with regard to Experiment 2. Because the prime–target SOA was set at 750 ms, faster participants might have been able to squeeze more processing into each trial and, hence, they might be better at encoding the associations between the prime and the target. Again, an analysis of variance was done that included Speed as a factor. This analysis revealed that, as in Experiment 1, neither the Speed \times Repetition Type or the Age \times Speed \times Repetition Type interactions were significant ($F_s < 1.2$, $p_s > .20$). The priming effects for fast and slow responders were not significantly different (19 ms vs. 15 ms, respectively). Moreover, although both fast and slow younger adults showed robust priming (38 ms and 25 ms, respectively), neither fast nor slow older adults showed any evidence for episodic priming (–1 ms and 3 ms).

Another alternative account might be the possibility that there are age differences in the ability to maintain attention to the prime–target relationship, which would be necessary to encode the associative relationships. There is some evidence suggesting that older adults are less able to maintain activation for a prime at long prime–target SOA's (Balota, Black, & Cheney, 1992). However, as already mentioned, the interval between the prime and the target in Experiment 2 was actually shorter than that in Experiment 1, yet Experiment 2 is where the large age differences were found.

Interaction Between Spacing and Test Delay

The results from the test trials in both experiments resulted in the expected interaction between spacing and test delay. In Experiment 1 this pattern was found in the pattern of episodic

priming for consistently repeated prime–target word pairs. Specifically, there was greater episodic priming for the massed than for the spaced repeated word pairs at the immediate test, but greater episodic priming for the spaced than for the massed repeated word pairs at the delayed test. This finding is relevant to a recent account of the spacing effect. Greene (1989, 1990) suggested that in implicit memory tasks such as perceptual identification and word fragment completion, the spacing effect arises from rehearsal strategies that individuals only engage in under intentional learning instructions. This account for the spacing effect does not appear to hold for Experiment 1 in which individuals were given instructions simply to name the words and it seems unlikely that individuals engaged in any rehearsal.

The substantial differences between the studies reported by Greene (1989, 1990) and the present experiments make it difficult to draw strong conclusions about why such different results were obtained. It may be the case that the tasks requiring more conscious attentional processing at retrieval, such as word fragment completion and perceptual identification, are more sensitive to manipulations such as learning intentionality than a primarily stimulus-driven task such as the speeded naming task used in Experiment 1.

As pointed out by Challis (1993), the sheer persistence of the spacing effect (and by extension, the spacing by test delay interaction) presents an important challenge to any proposed theoretical account. Numerous theories have been proposed to account for these effects with varying degrees of success (Challis, 1993; Crowder, 1976; Hintzman, 1974, 1976). Although we do not have any solid theory to account for the present results, these data have provided two additional data points that we believe are important in any theoretical account of the spacing effect. First, the spacing by test delay interaction can be obtained when the dependent measure is simply the speed to name the target as in Experiment 1. Second, the interaction in cued recall appears to be equivalent in younger and older adults despite sizable differences in overall performance (see also Balota, Duchek, & Paullin, 1989).

Effects of Repetition on the Duration of Naming Responses

The observation in Experiment 2 of a small but robust repetition effect in the duration of naming responses deserves some emphasis. At first glance, it would be surprising if the repetition of a word did not change characteristics of how the word is articulated. However, Fowler (1988) failed to find repetition effects on production durations in the context of a word list. Fowler and Housum (1987) observed the shortening of words repeated within a monologue of a speaker and Shields and Balota (1991) found that individuals shorten the later duration of a repeated target word within the production of isolated sentences. Taken together, these results appear to be consistent with the suggestion that the modulation of production durations might function as marking Given/New information (Clark & Clark, 1977) in conversation. However, although not ruling out the possibility that changes in production durations may function to mark Given/New information, the present results do suggest that production durations can also be influenced by fac-

tors operating outside the typical conversational context. Thus, it appears more likely that at least part of the modulation of production durations is a reflection of the continuous nature of a processing system in which influences of factors are not limited to one level in the system (e.g., pattern recognition) but instead are likely to cascade from pattern recognition into response output (Balota & Abrams, 1995; Balota, Boland, & Shields, 1989; Shields & Balota, 1991).

Conclusions

This study examined evidence for age related changes in the encoding of associative information. There have been numerous suggestions that older adults are less adept at the encoding of associative information. However, previous studies have been mixed in support of such age related changes. At first glance, Experiment 1 appeared to offer little support for age deficits in associative encoding. However, when the substantial age difference in overall speed of processing is taken into account, older adults show proportionately less episodic priming compared to younger adults. On the basis of the observation that output processes could contribute to the estimate of episodic priming in Experiment 1, and that age differences in more output-motor associative priming are small or nonexistent at least as reflected by performance in the SRT task (Howard & Howard, 1989), the second experiment attempted to eliminate this contribution by requiring naming responses only to the target in the prime-target pairs. This experiment revealed no significant episodic priming for older adults but robust priming for younger adults. Thus, these results support the notion of age related changes in the encoding of associative information.

Both experiments also exhibited evidence of an interaction between the spacing of repetitions and test delay. This interaction refers to the benefit for massed over spaced repeated items at an immediate test, and the benefit for spaced over massed repetitions at a delayed test. The results from Experiment 1 indicated that this interaction can be obtained in a task that minimizes retrieval processes. Both experiments also provided evidence that both younger and older adults produce this interaction in an equivalent manner, thereby extending the observations by Balota, Duchek, and Paullin (1989). The results further establish this interaction as a fundamental aspect of various forms of learning and memory.

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Received September 8, 1995

Revision received February 12, 1996

Accepted February 12, 1996 ■