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Spreading Activation in Episodic Memory: Further Evidence for Age Independence

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Seventy-two young (mean age = 25 years) and 72 old adults (mean age = 71 years) participated in an experiment that addressed the influence of episodic and semantic prime activation on speeded episodic recognition judgements. On each test block, subjects studied two paragraphs at their own pace to achieve a designated level of episodic recognition performance. Following the study period, subjects were presented a series of prime–target trials for speeded episodic recognition. The primes were either (a) episodically related to the target, (b) semantically related to the target, (c) episodically and semantically related to the target, or (d) episodically and semantically unrelated to the target. The stimulus onset asynchrony (SOA) between the primes and targets was either 200 msec, 600 msec, or 1000 msec to address age-related changes in the rate at which these different prime types influenced performance. The results indicated that, compared to young adults, the old adults (a) studied the paragraphs for a longer period of time, (b) responded to the targets more slowly, and (c) were less accurate in their episodic recognition decisions. Although there were these main effects of age, the young and old adults were influenced in a similar fashion by the different prime-target relationships and by the interactive influences of the prime–target relationships and SOA. Correlational analyses indicated that the pattern of priming effects was as similar across the two age groups as across two pseudo-groups that were matched on the age dimension. These results were viewed as further support for the notion that the characteristics of the spreading activation mechanism as reflected by prime–target manipulations are relatively stable across young and old adults.

An important finding in memory research is that older adults—those past the age of 60—exhibit memory deficits across a wide variety of tasks (see reviews by Craik, 1977; Burke & Light, 1981). Although this deficit is clearly

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documented, there is little agreement on an underlying theoretical account. The goal of the present study is not to present a formal model of this age-related memory deficit but, rather, to address the utility of an important theoretical construct, spreading activation, in accounting for this memory deficit.

According to the spreading activation framework, memory is organized via representations (nodes) that are interconnected by associative pathways. When one of these memory representations becomes activated, either via internal thought or stimulus presentation, activation spreads along the associative pathways to related areas of the memory network. This extra activation makes these related areas more available for subsequent processing. In this way, spreading activation has been viewed as the main driving force of the processing system and keeps the system attuned to task-relevant information (e.g. Anderson, 1983a, 1983b).

The present research addresses spreading activation in an episodically defined memory structure. This research follows closely the study-test paradigm used by Ratcliff and McKoon (1981). In this paradigm subjects study a paragraph such as the one displayed in the top portion of Figure 1. As shown, this paragraph consists of five sentences in which the object of the predicate in each sentence is the subject of the next sentence. If one assumes a simple network representation, then this paragraph might be represented as in the bottom portion of Figure 1 (see Anderson, 1983a; Ratcliff & McKoon, 1981). Here one can see a propositional representation for the sentences in

Example Study Paragraph

S1) The umbrella protects the carpet. (N1 V N2)
S2) The carpet is under the workman. (N2 V N3)
S3) The workman moves the rug. (N3 V N4)
S4) The rug impresses the guest. (N4 V N5)
S5) The guest hears the doorbell. (N5 V N6)

Memory Representation

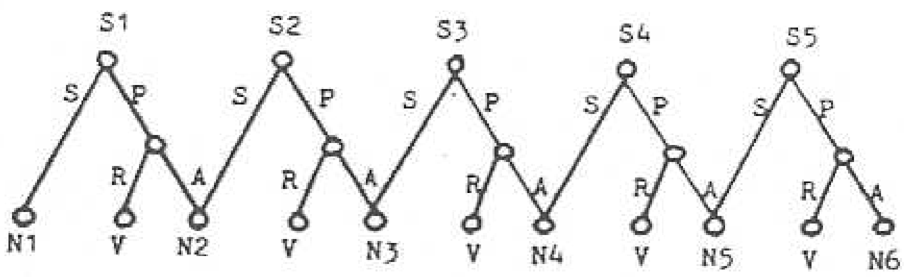

FIG. 1. An example study paragraph and its corresponding memory representation (N = noun, V = verb, S = subject, P = predicate, R = relation, A = argument).

which each sentence involves both a subject and a predicate, the latter of which can be further broken down into a relation and an argument. Moreover, one can see that there is a terminal node available for each of the content words in each sentence (e.g., N1, V1, N2, etc.) which converge on a sentence node (e.g. S1, S2, etc.)

Once a memory representation is assumed, it is possible to address the characteristics of the mechanism(s) that are used to retrieve information from that network. This can be achieved through an episodic priming procedure. On each trial, a prime is followed by a target word that may or may not have occurred in the studied paragraph. The influence of the prime on the speed and accuracy in making an episodic recognition decision about the target can be used to reflect the organization of the memory network and the characteristics of the retrieval mechanism(s). The major assumption is that if the prime is a word from the studied paragraph, then it will activate its underlying memory representation, and activation will spread from that representation throughout the paragraph structure. Thus, the target's memory representation should be preactivated via the presentation of a prime from the same memory structure, thereby decreasing response latency.

There is already some evidence available regarding age-related differences in episodic activation (Howard, 1985; Howard, Heisey, & Shaw, 1986; Rabinowitz, 1986). Although the data from these studies overall suggest that both young and old adults benefit from episodically related primes, there are a number of age-related differences that have been observed. First, Howard and colleagues found an age-related deficit in the amount of facilitation when subjects were given only one study period, but this deficit was eliminated when subjects were given two study periods. Second, they found evidence that backward priming from an object to a subject within a sentence was substantially lower for old adults than forward priming, whereas, for young adults, there was no appreciable difference between these types of priming. Third, they found that old adults were insensitive to the distinction between *within* and *between* propositional representations, whereas young adults produced larger priming effects for *within* propositional pairs compared to *between* propositional pairs.

The present study included a number of changes from the past studies, which should provide further information concerning episodic priming in young and old adults: (1) In the present study, subjects did not make an episodic decision concerning the status of the prime item. In all of the previous studies addressing age-related changes in episodic priming, along with many of the studies addressing episodic priming in young adults (e.g. McKoon & Ratcliff, 1979; McKoon, Ratcliff, & Dell, 1985), subjects responded to both primes and targets in a type of running episodic recognition test. Thus, in these studies, episodic priming effects typically reflect target trials in which the subject responded "yes" to the word on the previous trial (i.e. the prime). In the present study, subjects were not required to make an episodic decision concerning the prime item, and therefore any influence of the prime should be a better reflection of activation from the prime to the target rather than processes tied to the decision concerning the episodic nature of the prime. (2) Because subjects did not respond to the prime in the present study, we were able to manipulate the stimulus onset asynchrony (SOA) between the prime and target to address any age-related changes in the build-up of activation across time. This has yet to be directly controlled in the past ageing studies. (3) The present study involved an unlimited free-study paradigm, with continuous feedback throughout the experiment. This procedure was used because it seemed important to address any age-related differences in the activation retrieval patterns from memory networks that subjects studied sufficiently to reach a designated level of performance.

We shall now turn to a brief description of the specific prime-target manipulations.

Studied Targets

Age, SOA, and Distance. Two important issues addressed in the present study are whether there are age-related changes in (1) the rate of build-up of activation and/or (2) the influence of "distance" within the memory network that the activation must traverse. The influence of prime-target distance was addressed by comparing performance on a target word (e.g. *CARPET*) when it was primed by either a near prime (e.g. *workman*) or a more distant prime (e.g. *guest*—see Figure 1). The rate at which the activation builds up for these two conditions was addressed by comparing performance at 200-, 600-, and 1000-msec prime–target SOAs. At SOAs ranging between 50 and 350 msec, Ratcliff and McKoon (1981) found that activation began at the same time for the near and far conditions but eventually reached higher levels of activation for the near condition than the far condition (see their Experiment 2). A major question raised in the present study is whether old and young adults' activation patterns will be influenced in a similar fashion by distance across a wider range of SOAs, i.e. 200 to 1000 msec.

These comparisons are a natural extension of a recent study by Balota and Duchek (1988). They addressed whether there were age-related changes in the rate of activation build-up for both strong and weak related prime–target pairs in a *semantic* priming pronunciation experiment. They found that activation built up at a similar rate and was influenced in a similar fashion by distance (strength) within the semantic network for young and older adults.[1]

[1]Howard, Shaw, and Heisey (1986) reported evidence that is somewhat different from the Balota and Duchek (1988) results. They found, at a 150-msec prime target SOA, a significant

Thus, the present episodic distance manipulation is a clear counterpart to the Balota and Duchek semantic distance study.

Semantic Activation and Episodic Recognition. The present study also affords a number of comparisons addressing the impact of different combinations of episodic and semantic information on speeded episodic recognition. These conditions should provide information concerning age-related changes in sensitivity to episodic and/or semantic activation on episodic recognition performance. Thus, as shown in Table 1, there are conditions that involve all possible combinations of semantic and episodic activation from the prime to the target.

Consider, for example, the semantically related *and* episodically related condition (SR&ER). As shown in Table 1, study paragraphs included two content words that were semantically related, e.g. *rug–CARPET*. Thus, when the prime word *rug* is presented, it should produce both episodic activation for *CARPET* and semantic activation for the concept underlying *CARPET*. In order to isolate the impact of episodic activation from semantic activation, there is the semantically related *and* episodically unrelated condition (SR&EU). Here, the prime *buzzer* is semantically related to the target *DOORBELL*, but this prime did not occur in the studied paragraph. Finally, in order to isolate the impact of semantic activation, the SR&EU condition will be compared to the SU&EU condition in which the prime was neither semantically nor episodically related to the target, e.g. *nut–DOORBELL*.

Non-Studied Target Conditions

The present episodic priming conditions also provide comparisons concerning non-studied targets. In fact, it is *necessary* to have similar prime conditions for non-studied targets to address directly how activation is influencing retrieval processes. For example, if only the studied targets included conditions with semantically related primes, then subjects could base their episodic decisions on the presence of a semantic relationship

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34-msec priming effect for younger adults and a non-significant 9-msec priming effect for the older adults. Although the interaction between prime relatedness and age did not reach significance, the age-related difference in the patterning of means was different from the additivity reported by Balota and Duchek. One possible reason for this difference is that the Howard et al. study involved a lexical decision task and the Balota and Duchek study involved a pronunciation task. Possibly, some of the priming effect found for the young adults at the 150-msec SOA was due to a post-access checking for a relationship between the prime and target. If this is correct, then it is quite interesting that this checking process is slowed sufficiently in the older adults that it does not influence performance at the 150-msec SOA. In any case, there is increasing evidence that the lexical decision task involves post-access decision mechanisms that could compromise one's interpretation of spreading activation effects (e.g. Balota & Lorch, 1986; Seidenberg, Waters, Sanders, & Langer, 1984).

TABLE 1
Prime-Target Conditions for *Studied* Targets and Corresponding Activation Patterns for an Example Study Paragraph

Example Study Paragraph

The umbrella protects the carpet.
The carpet is under the workman.
The workman moves the rug.
The rug impresses the guest.
The guest hears the doorbell.

Condition	*Prime*	*Target*	*Sem Act*	*Epis Act*
SU&ER (Near)	workman or guest	CARPET DOORBELL	0	++
SU&ER (Far)	guest or workman	CARPET DOORBELL	0	+
SR&ER	rug	CARPET	+	+
SR&EU	buzzer	DOORBELL	+	0
SU&EU	nut or lion	CARPET DOORBELL	0	0
NEUTRAL	xxxxx or blank	DOORBELL DOORBELL	0	0
	xxxxx or blank	CARPET CARPET	0	0

S refers to semantic information.
E refers to episodic information.
U refers to unrelated.
R refers to related.

between the target and the prime. Hence, the subject could respond "yes" whenever a prime–target relationship was found. In fact, this strategy would have been effective in the Rabinowitz (1986) study. Such a search for a relationship between a prime and target could be quite independent of the activation processes from the prime to the target (see Balota & Lorch, 1986; Neely, 1986).

The prime conditions for the non-studied targets are displayed in Table 2. First, it should be noted that there are two major non-studied target conditions: (1) In the *unrelated* non-studied target conditions, displayed in

TABLE 2
Prime-Target Conditions for *Non-Studied* Targets and Corresponding Activation Patterns for an Example Study Paragraph

Example Study Paragraph

The umbrella protects the carpet.
The carpet is under the workman.
The workman moves the rug.
The rug impresses the guest.
The guest hears the doorbell.

Condition	*Prime*	*Target*	*Sem Act*	*Epis Act*
Unrelated Non-Studied Target				
SU&ER	workman	TIGER	0	+
	or			
	guest	TIGER		
SR&EU	lion	TIGER	+	0
SU&EU	nut	TIGER	0	0
	or			
	buzzer*	TIGER		
NEUTRAL	xxxxx	TIGER	0	0
	or			
	blank	TIGER		
Related Non-Studied Target				
SU&ER	workman	HOST	0	+
SR&ER	guest	HOST	+	+
SU&EU	nut	HOST	0	0
	or			
	buzzer*	HOST		
NEUTRAL	xxxxx	HOST	0	0
	or			
	blank	HOST		

* Actually, the prime word *buzzer* is indirectly episodically related. It is related to a word (e.g. *doorbell*) in the studied paragraph. However, preliminary analyses indicated that this indirect episodic relationship did not influence performance; compared to the totally unrelated prime condition (e.g. when *nut* was presented as the prime). Therefore, in order to obtain more stable estimates for the SU&EU condition, both primes were considered SU&EU.

the top half of Table 2, the target is semantically unrelated to all of the content words in the studied paragraph. (2) In the *related* non-studied target conditions, displayed in the bottom half of Table 2, the target is semantically related to one word in the studied paragraph.

For the purpose of brevity, we will note only a few of the issues addressed by the prime conditions for the non-studied targets. (1) Consider the prime condition in which the prime item is from the studied paragraph and unrelated to the non-studied target (e.g. *workman–TIGER*). This condition should provide information about the impact of episodic activation on rejecting a non-studied target. (2) Consider the prime condition in which the prime item is semantically related to the non-studied target but unrelated to the memory structure (e.g. *lion–TIGER*). This condition should provide information about the impact of semantic activation on rejecting a non-studied target. (3) Consider the condition in which the prime item is related to the non-studied target *and* related to the memory structure (e.g. *guest–HOST*). Here the subject will be receiving two sources of activation on trials in which the correct response is to reject the non-studied target.

Neutral Baselines

As shown in Tables 1 and 2, there were two different neutral baselines (*xxxxx* and *blank*). These baselines were included to measure both facilitation and inhibition effects (cf. Neely & Durgunoglu, 1985). However, as described below, the neutral baselines produced an intriguing pattern of more inhibition for the old adults compared to the young adults. Because of this unexpected age-related difference in processing neutral baselines, the major comparisons of interest will be made across the non-neutral conditions displayed in Tables 1 and 2.

Design

On each of 24 test blocks per testing session, subjects studied two paragraphs of the structure displayed in Figure 1. After studying the paragraphs, subjects received 8 prime–target trials, reflecting the various conditions displayed in Tables 1 and 2. Each subject participated in two testing sessions that were separated by 24 to 72 hours. Subjects received the same set of study paragraphs on both days of testing. The second testing was included to increase the power of the design. The design included the following factors: Age (Young vs. Old), Target Status (Studied vs. Non-Studied Target), SOA (200 msec, 600 msec, 1000 msec) and Prime type.

Method

Subjects. Seventy-two old adults (26 males and 46 females) and 72 young adults (26 males and 46 females) participated in the experiment. The mean age for the old adults was 70.9 years and ranged between 65 and 80 years ($SD = 3.81$), and the mean age for the young adults was 24.5 years and ranged between 18 and 36 years ($SD = 5.28$). The old adults had a slightly lower education level (mean = 13.8 years) compared to the young adults (mean = 14.9 years). However, the old adults scored slightly higher (mean = 29.6) on the WAIS vocabulary subsection, Items 21–40, compared to the young adults (mean = 28.9). Only the difference in age reached significance.

All of the old adults were recruited from the community. For the young adults, 36 (13 males and 23 females) were students at Washington University, and 36 (13 males and 23 females) were non-students recruited from the community. This was necessary to ensure that any observed age-related differences were not due to the fact that young adults were students and old adults were non-students. The non-students were older (mean age = 28.5 years, range 20–36 years) than the students (mean age = 20.6 years, range 18–32 years), had slightly more education (mean = 15.5 years) than the students (mean = 14.5 years) and scored slightly higher on the WAIS vocabulary subtest (mean = 29.1) than the students (mean = 28.6). Only the age difference reached significance ($p < 0.01$). In addition, although the young students responded on average 187 msec faster than the young non-students, this factor did not participate in any interactions in preliminary analyses and will therefore be ignored in the results and discussion sections.

Apparatus. The experiment was controlled by an Apple IIe microcomputer equipped with a Mountain Hardware clock. Stimulus presentation was synchronized to the raster scanner pulse. The "1" and "0" keys on the Apple keyboard were used for the subjects' responses.

Materials. Before presenting the details of list construction, one should note that, as shown in Tables 1 and 2, there were two different studied targets (e.g. *CARPET* and *DOORBELL*) and two different non-studied targets (e.g. *TIGER* and *HOST*) per test paragraph. One might be concerned that the comparisons of interest might include influences due to different target items/condition. However, the only comparison that is reported in the results that did not include complete counterbalancing of target words across conditions was the impact of semantic relatedness for the studied targets. Moreover these two studied targets were approximately matched on length in letters (mean = 5.33 and 5.48), syllables (mean = 1.7 and 1.5), and Kučera and Francis (1967) printed word frequency (mean = 50 and 51 per million occurrences). Likewise, the two non-studied targets were approximately matched on length in letters (mean = 5.2 and 5.3), syllables (mean = 1.5 and 1.6), and word frequency (mean = 64 and 46 per million occurrences). Finally, as described below, (a) no prime or target was repeated for a given subject within a testing session, and (b) each item and condition was completely counterbalanced across Age, SOA, and Day of testing.

There were 48 test paragraphs and 4 practice paragraphs constructed such that there were no obvious semantic relationships across paragraphs. In each paragraph there were two semantically related words that were based on the materials used by Balota and Duchek (1988). Of the 48 test paragraphs, 24 were designated as semantically related *near* paragraphs and 24 as *far* paragraphs. In the 24 semantically related *near* paragraphs the first related word occurred as the object of Sentence 1 and the subject of Sentence 2, and the second related word occurred as the object of Sentence 3 and the subject of Sentence 4. In the 24 semantically related *far* paragraphs, the first related word occurred as the object of Sentence 1 and the subject of Sentence 2, and the second related word occurred as the object of Sentence 5. In contrast to the semantically related near paragraph displayed in Tables 1 and 2, the following is an example of a semantically related *far* paragraph.

The man polishes the knife.
The knife cuts the wire.
The wire supports the shelf.
The shelf contains the hats.
The hats cover the fork.

Because preliminary analyses did not yield any systematic effects of or interactions with this semantic distance factor, this factor will be ignored in the results and discussion sections.

In addition to the construction of the paragraphs, it was necessary to select five further words to complete the prime target conditions. These were (1) the semantically related and episodically unrelated prime for the studied target (e.g. *buzzer* in Table 1), (2) the related non-studied target (e.g. *HOST* in Table 2), (3) the unrelated non-studied target (e.g. *TIGER* in Table 2), (4) the semantically related prime for the non-studied target (e.g. *lion* in Table 2), and (5) the semantically and episodically unrelated prime for both the studied and non-studied targets (*nut* in both Tables 1 and 2).

After the materials were constructed, the selection of prime–target pairs for a given subject occurred in the following fashion. First, for each paragraph, prime–target pairs were assigned to eight different test quadruples. Each test quadruple consisted of two studied target conditions and two non-studied target conditions. The only constraint on the assignment of prime–target pairs to a given test quadruple was that no word was repeated within a test quadruple. In producing a given list, test quadruples were rotated across both paragraphs and subjects. For example, if a subject received test quadruple 1 for paragraph 1, then for paragraph 2, that subject would receive test quadruple 2. Likewise, if a given test quadruple was designated test quadruple 1 for subject n, then for subject $n \pm 1$ that test quadruple would be designated test quadruple 2.

With this list construction procedure, for each subject × SOA cell there were 8 observations for each of the non-studied target conditions. For the studied target conditions there were: (a) 12 observations for both the SU&ER *near* conditions and the SU&ER *far* conditions; (b) 8 observations for the SR&ER and the SR&EU prime conditions; (c) 7 observations for the SU&EU condition, (d) 9 observations for the neutral condition that involved the target that was semantically related to a word from the paragraph (e.g. *xxxxx-CARPET*), and (e) 8 observations for the neutral condition that involved the target that was semantically unrelated to any other word from the paragraph (e.g. *xxxxx-DOORBELL*).

After lists were constructed for a given subject, the paragraphs and the prime–target pairs within a given test block were randomly ordered anew for each subject and test block.

Procedure. On each trial 2 paragraphs were presented for study, followed by 8 prime–target trials, four from each paragraph. The first paragraph was presented on lines 2–6 and the second paragraph was presented on lines 11–15. The subjects were told that when they felt they had sufficiently studied the paragraphs to achieve an accuracy level of 85 to 90% correct on the recognition test, they should press the "1" key on the keyboard to begin the recognition test. They were told that on each trial of the recognition test two words would be presented. They should read the first word silently to themselves and make their recognition decision only on the second word, independent of whether the first word appeared in one of the two studied paragraphs. If the second word appeared in one of the paragraphs, they were to press the "0" button, and if the second word did not occur in either of the paragraphs, they were to press the "1" button. The instructions emphasized that subjects should attempt to minimize their study time and response latency, while keeping their accuracy between 85 and 90% correct.

Subjects were given feedback to monitor their performance. After each block of eight recognition test trials they received feedback regarding their study time and accuracy for the previous block of trials. If on the previous block of trials they made 3 or more errors (62.5% correct or less), then the following message was presented: "You made too many ERRORS on the last block and so you may wish to increase your study time on the next two paragraphs." If on the previous block of trials the subject made no errors, then the following message was presented: "You are performing near perfectly at recognizing the words. You may wish to decrease your study time slightly." In addition to these messages, on each trial subjects received feedback regarding their average study time across blocks and average accuracy across blocks. Also, the following message was presented after each block: "Remember, please keep studying the paragraphs at a rate which keeps your overall accuracy between 85 and 90% correct."

The exact sequence of events on each prime–target recognition trial was as follows: (a) a row of three asterisks separated by blank spaces in the centre of the screen for 300 msec; (b) a blank screen for 300 msec; (c) a warning tone for 150 msec; (d) a blank screen for 300 msec; (e) the lower-case prime in the centre of the screen for either 200 msec, 600 msec, or 1000 msec; (f) the prime erased, and the upper-case target at the same location as the prime; (g) the subject's keypress of either the "1" or "0" button; (h) if the subject was correct, a 2-sec intertrial interval; if the subject was incorrect, an "ERROR!!!" message in the centre of the screen for 750 msec, followed by the message "Please type in a 1 or 0 to continue"; (i) on error trials, the subject's keypress followed by the 2-sec intertrial interval.

Subjects were seated approximately 60 cm from the CRT. After the instructions, the subjects received two practice blocks. The experimenter remained in the room during the practice blocks to ensure that the subject fully understood the task. There was a brief break period after the second practice block, during which the experimenter left the room, along with a break period after the 26th block of trials. Subjects were informed that they could also take breaks whenever the feedback information was presented.

All testing sessions lasted between 1 hour and 15 minutes and 1 hour and 45 minutes. Each subject participated in two different testing sessions that were separated by 1 to 3 days. The mean interval between testing sessions was kept constant across age groups at 1.8 days. The complete set of 52 paragraphs was presented on both days, and the procedure was precisely the same on the second day as on the first day. The only difference was that on the second day subjects received a different test quadruple for each of the studied paragraphs.

Results and Discussion

Each subject's overall mean response latency and standard deviation was calculated separately for each day of testing. Any response latency exceeding 3 standard deviations above or below the subject's mean for a given day or below 175 msec was treated as an outlier. The young adults produced 3.1% outliers, and the old adults produced 3.9% outliers. From the remaining correct responses, a mean response latency was calculated for each subject by condition cell. Also, a mean percentage correct was calculated based on the correct responses that were not outliers.

As a way of organizing the results, global analyses on age-related changes in performance will be presented first. These will be followed by analyses that focus on performance as a function of prime condition. All significant effects have p values less than 0.05.[2]

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[2]The error terms from the analyses of variance that are reported are based on variablility across subjects. It should be noted, however, that because items were counterbalanced across subjects, this error term also includes variability across items. In order to further address generality across items, we re-computed the ANOVAs with *List* as a factor. This factor had eight

Global Analyses on Performance

Study-time, Accuracy, and Age. The old adults studied the paragraphs for a significantly longer period of time (40.3 sec) than the young adults (19.5 sec). However, the old adults' accuracy (88%) was still significantly lower than the young adults' (92%). (Note that these figures do not include outliers, because we are here interested in the actual feedback that the subjects received. Outliers were removed after all data were collected.) Thus, the old adults were indeed using extra study time to increase their overall accuracy to an acceptable level, i.e. between 85% and 90% correct. Although the old adults had free study and did increase their study time, they still did not reach the same level of accuracy exhibited by the young adults.

Neutral Baselines for Young and Old Adults. As noted, the neutral baseline condition (*xxxxx*) was originally included to measure facilitation and inhibition effects. However, a preliminary analysis of the data indicated that all of the non-neutral prime conditions produced larger facilitation effects, compared to this neutral baseline, for the old adults than for the young adults (also see Chiarello, Church, & Hoyer, 1985). Moreover, the differences among the various non-neutral prime conditions were not any larger for the old adults compared to the young adults. Thus, it appeared that the *xxxxx* prime was producing an age-specific inhibition effect.

In an attempt to address the possibility that old adults were being disrupted by the non-lexical nature of the *xxxxx* prime, after the first 30 subjects had participated in each age group, the neutral *xxxxx* prime was switched to the word *blank*. Table 3 presents the data for studied and non-studied targets as a function of the Type of Neutral Prime (i.e. *xxxxx* vs. *blank*), Non-Neutral vs. Neutral Prime, and Age.

An ANOVA on the response latency data yielded two noteworthy effects. (1) An interaction between Age and Neutral vs. Non-Neutral prime, $F(1, 140) = 32.87$, $MSe = 40{,}910$, indicated that old adults produced a much larger difference between non-neutral and neutral primes than young adults, 99 msec vs. 22 msec, respectively. (2) There was a significant three-way interaction between Age, *xxxxx* vs. *blank*, and Neutral vs. Non-Neutral Prime, $F(1, 140) = 5.32$, $MSe = 40{,}910$. As shown in Table 3, this interaction indicated that the age-related difference decreased when the word *blank* was

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levels that referred to the consistent quadruple assignment across subjects for the study paragraphs. The results of these ANOVAs indicated that List did not participate in any significant interactions with prime condition or age. In fact, the only significant effects that included List were main effects in (a) the ANOVA on the *near* vs. *far* episodically related primes and (b) the ANOVA on *Related* Non-Studied targets (both $ps < 0.05$). Because List did not participate in any significant interactions with the variables of interest, it appears that the major effects reported also generalize across items.

TABLE 3
Mean Response Latency (msec) and Percent Correct as a Function of Age, Studied vs. Non-Studied Target, Neutral vs. Non-Neutral Prime, and blank vs. xxxxx

	Neutral Prime		*Non-Neutral Prime*		*Difference*	
	msec	%	*msec*	%	*msec*	%
Studied Targets						
Young						
xxxxx	718	86.5	693	87.9	25	−1.4
blank	812	87.8	786	87.8	26	0.0
Old						
xxxxx	1354	80.0	1226	80.8	128	−0.8
blank	1225	80.2	1167	83.4	58	−3.2
Non-Studied Targets						
Young						
xxxxx	767	89.0	748	91.1	19	−2.1
blank	901	88.4	884	89.7	17	−1.3
Old						
xxxxx	1592	82.2	1462	86.5	130	−4.3
blank	1409	87.1	1331	88.2	78	−1.1

used as the neutral prime compared to when *xxxxx* was used as the neutral prime. Thus, at least part of the age-specific inhibition produced by the neutral prime does appear to be related to the lexical status of the neutral prime.

Because of this age-related difference in processing neutral primes, the non-neutral prime conditions will be directly compared instead of comparing these conditions to their corresponding neutral baselines. As Jonides and Mack (1984) and de Groot, Thomassen, and Hudson (1982) have argued, one can be easily misled by the use of an inappropriate neutral baseline.

Age-Related Differences and Response Biases. As shown in Table 3, response latencies were considerably faster to studied targets (998 msec) compared to non-studied targets (1137 msec), $F(1, 140) = 109.42$, $MSe = 165{,}053$. However, this impact on response latency was compromised by less accurate performance for studied targets (84.3%), compared to non-studied targets (86.1%), $F(1, 140) = 25.99$, $MSe = 0.045$. Thus, there is evidence for a bias to respond "yes" in the data. More importantly, an interaction between Age and Studied vs. Non-Studied Target, $F(1, 140) = 23.36$, $MSe = 165{,}053$, indicated that the young adults produced a smaller bias in response latency (76 msec) than the old adults (200 msec). The interaction between Age and Studied vs. Non-studied target did not reach significance [$F(1, 140) = 2.78$, $MSe = 0.045$, $p < 0.10$] in the accuracy data. Thus, it appears that both young and old adults had a bias to respond "yes" and that this bias was stronger for old adults, at least as reflected by the response latency data. Rabinowitz (1986) reported a similar age-related pattern in an episodic priming experiment.

Analyses Focusing on Age-Related Differences Across Prime Conditions

In the following sections, the data are presented separately to emphasize theoretically motivated comparisons across the prime conditions. In each section, a description of the data presented in tables will be followed by the results from the appropriate mixed-factor ANOVAs. Any significant mean comparisons based on the error term from the Age × SOA × Prime condition interaction will be indicated by asterisks in the tables.

Studied Targets

1. Spreading Activation, Rate and Distance. A major goal of the present study was to address whether there are age-related differences in the rate at which activation spreads within an episodic memory structure. Table 4 displays the mean response latency and percentage correct as a function of Age, SOA, and distance between the prime and target within the episodic memory network. As one can see, the near condition produced overall faster

Mean Response Latency (msec) and Percent Correct as a Function of Near and Far Episodically Related Primes, SOA (msec), and Age

	Near		*Far*		*Far–Near*	
SOA	*msec*	%	*msec*	%	*msec*	%
Young Adults						
200	748	89.9	759	87.0	11	−2.9*
600	730	90.3	763	88.9	33*	−1.4
1000	743	88.4	765	89.7	22	+1.3
Mean	740	89.5	762	88.5	22	−1.0
Old Adults						
200	1193	86.7	1211	84.0	18	−2.7*
600	1174	85.5	1219	83.8	45*	−1.7
1000	1195	83.3	1200	83.5	5	+0.2
Mean	1187	85.2	1210	83.8	23	−1.4

response latencies than the far condition, $F(1, 142) = 7.70$, $MSe = 27{,}500$. In addition, the main effect of distance on the accuracy data approached significance, $F(1, 142) = 2.99$, $MSe = 0.021$, $p < 0.10$. More importantly, neither the interaction between Age and Distance nor the interaction between Age, Distance, and SOA approached significance for either the response latency or the accuracy data (all $Fs < 1.00$).

As shown in Table 4, the differences between the near and far conditions were remarkably similar across age groups. As indicated by the asterisks, planned comparisons indicated that the only SOA to produce a significant distance effect in the response latency data was the 600-msec SOA, and this SOA produced significant effects for both the young and old adults. Moreover, similar comparisons for the accuracy data indicated that only the 200-msec SOA produced a significant effect, and again this was the case for both age groups.

2. *Semantic and Episodic Activation for Studied Targets.* A second issue addressed is whether young and old adults differentially use semantic and episodic information to make recognition decisions about a studied target. Table 5 displays the mean response latency and accuracy for the SU&EU, the SR&EU, and the SR&ER conditions as a function of Age and SOA, and Table 6 displays the differences across these conditions.

The data displayed in Table 6 can be summarized as follows: (1) As shown in Column 1, the presence of a semantic relationship for episodically

TABLE 5
Mean Response Latency (msec) and Percent Correct for the Studied Targets as a Function of Semantic and Episodic Prime-Target Relationship, SOA (msec), and Age

	SU&EU		*SR&EU*		*SR&ER*	
SOA	*msec*	%	*msec*	%	*msec*	%
Young Adults						
200	741	89.6	766	80.4	721	86.3
600	734	90.1	719	86.5	686	86.3
1000	744	89.8	730	85.1	674	89.6
Mean	740	89.8	738	84.0	694	87.4
Old Adults						
200	1158	84.7	1215	72.7	1155	82.6
600	1100	84.4	1143	75.5	1121	79.5
1000	1200	84.5	1200	77.3	1129	80.7
Mean	1153	84.5	1186	75.2	1135	80.9

TABLE 6
Mean Differences in Response Latency (msec) and Percent Correct for the Studied Targets as a Function of Semantic and Episodic Prime-Target Relationship, SOA (msec), and Age

	SU&EU–SR&EU		*SU&EU–SR&ER*		*SR&EU–SR&ER*	
SOA	*msec*	%	*msec*	%	*msec*	%
Young Adults						
200	−25	+9.2	20	+3.3	45*	−5.9*
600	15	+3.6	48*	+3.8	33	+0.2
1000	14	+4.7*	70*	+0.2	56*	−4.5*
Means	1	+5.8	46	+2.4	45	−3.4
Old Adults						
200	−57*	+12.0*	3	+2.1	60*	−9.9*
600	−43	+8.9*	−21	+4.9*	22	−4.0
1000	0	+7.2*	71*	+3.8	71*	−3.4
Means	−33	+9.4	18	+3.6	51	−5.8

unrelated prime–target pairs actually disrupts recognition of the target. This disruption primarily occurs at the shorter SOAs and is stronger in the accuracy data than in the response latency data. (2) As shown in Column 2, the presence of both a semantic and episodic prime–target relationship produces considerable facilitation in the response latency data compared to the absence of both types of information. It should be noted, however, that this pattern is compromised by the accuracy data. There is some evidence of a speed–accuracy tradeoff in this column. (3) As shown in Column 3, the presence of an episodic relationship for prime–target pairs that are semantically related produces considerable facilitation in both accuracy and response latency. (4) The above patterns occur for both the young and the old adults.

The ANOVA on the response latency data yielded a significant effect of prime condition, $F(2, 284) = 11.04$, $MSe = 46{,}571$, and a significant SOA × Prime Condition interaction, $F(4, 568) = 2.53$, $MSe = 38{,}214$. Neither the Age × Prime Condition [$F(2, 284) = 1.59$, $MSe = 46{,}571$, $p > 0.20$] nor the Age × SOA × Prime Condition interactions ($F < 1.00$) approached significance. The ANOVA on the accuracy data yielded precisely the same pattern—that is, there was a significant main effect of Prime Condition, $F(2, 284) = 29.86$, $MSe = 0.042$, and a significant interaction between SOA and Prime Condition, $F(4, 586) = 2.51$, $MSe = 0.034$. Again, neither the Age × Prime Condition [$F(2, 284) = 1.45$, $MSe = 0.042$, $p > 0.20$] nor the Age × SOA × Prime Condition interactions ($F < 1.00$) approached significance.

Non-Studied Targets

3. Unrelated Non-Studied Targets. Table 7 displays the mean response latency and percentage correct for the SU&EU, SR&EU, and SU&ER Prime Conditions as a function of Age and SOA for the non-studied targets that were unrelated to any words in the studied paragraph. Table 8 displays the differences across the Prime Conditions.

The data in Table 8 can be summarized as follows: (1) As shown in Column 1, the presence of a prime–target semantic relationship for episodically unrelated prime-target pairs produces disruption in both response latency and accuracy. This disruption is somewhat larger in accuracy at the 600- and 1000-msec SOAs. Note that such a disruption was also found for the studied targets described above. (2) As shown in Column 2, the episodic activation produced by a prime from the studied paragraph had relatively little impact on performance for the non-studied unrelated targets. (3) As shown in Column 3, there was considerable disruption produced by the presence of semantic activation due to a prime–target semantic relationship, compared to episodic activation due to a prime from the studied paragraph. This disruptive effect occurred only at the 600- and 1000-msec SOAs. (4) The young and old adults again showed similar effects across conditions.

The results of the ANOVA on the mean response latency yielded a significant main effect of Prime Condition, $F(2, 284) = 12.87$, $MSe = 38{,}879$; however, the interaction between SOA and Prime Condition did not reach

TABLE 7
Mean Response Latency (msec) and Percent Correct for the *Unrelated* Non-Studied Targets as a Function of Semantic and Episodic Prime-Target Relationship, SOA (msec), and Age

	SU&EU		*SR&EU*		*SU&ER*	
SOA	*msec*	%	*msec*	%	*msec*	%
Young Adults						
200	796	95.3	832	92.2	790	92.9
600	799	96.2	824	90.8	774	95.3
1000	814	93.8	861	88.7	776	95.2
Mean	803	95.1	839	90.6	780	94.5
Old Adults						
200	1353	92.8	1370	90.1	1369	91.0
600	1332	94.5	1398	87.4	1327	94.1
1000	1341	93.8	1355	87.4	1326	93.4
Mean	1342	93.7	1374	88.3	1341	92.8

TABLE 8
Mean Differences in Response Latency (msec) and Percent Correct for the *Unrelated* Non-Studied Targets as a Function of Semantic and Episodic Prime-Target Relationship, SOA (msec), and Age

	SU&EU–SR&EU		*SU&EU–SU&ER*		*SR&EU–SU&ER*	
SOA	*msec*	%	*msec*	%	*msec*	%
Young Adults						
200	−36*	+3.1*	6	+2.4	42	−0.7
600	−25	+5.4*	25	+0.9	50*	−4.5*
1000	−47*	+5.1*	38	−1.4	85*	−6.5*
Mean	−36	+4.5	23	+0.6	59	−3.9
Old Adults						
200	−17	+2.7	−16	+1.8	1	−0.9
600	−66*	+7.1*	5	+0.4	71*	−6.7*
1000	−14	+6.4*	15	+0.4	29	−6.0*
Mean	−32	+5.4	1	+0.9	34	−4.5

significance [$F(2, 284) = 1.06$, $MSe = 37{,}980$]. More importantly, neither the Age × Prime Condition, nor the Age × SOA × Prime Condition interactions approached significance (both $Fs < 1.05$). The ANOVA on the percentage correct data yielded a significant effect of Prime Condition, $F(2, 284) = 30.96$, $MSe = 0.020$, and a significant SOA × Prime Condition interaction, $F(4, 568) = 3.77$, $MSe = 0.018$. Again, neither the Age × Prime Condition nor the Age × SOA × Prime Condition interactions approached significance (both $Fs < 1.00$).

4. Related Non-Studied Targets. Table 9 displays the mean response latency and percentage correct data for the SU&EU, SR&ER, and the SU&ER prime conditions for non-studied targets that were related to words in the studied paragraphs. Table 10 displays the differences across the prime conditions.

The data in Table 10 can be summarized as follows. (1) As shown in Column 1, the presence of both a semantic and episodic relationship between the prime and non-studied target produced considerable facilitation in response latency and accuracy compared to a condition in which neither relationship was available. This effect appeared to be larger, especially in response latency, at the 600-msec and 1000-msec SOAs. Note that such facilitation was also found for the studied targets described above. (2) As shown in Column 2, the presence of only episodic activation from the prime produced only a small amount of facilitation in accuracy at the 1000-msec

TABLE 9
Mean Response Latency (msec) and Percent Correct for the Non-Studied *Related* Targets as a Function of Semantic and Episodic Prime-Target Relationship, SOA (msec), and Age

	SU&EU		*SR&ER*		*SU&ER*	
SOA	*msec*	%	*msec*	%	*msec*	%
Young Adults						
200	862	85.4	819	90.5	854	87.0
600	877	85.1	789	92.8	863	86.3
1000	878	84.6	784	91.4	842	87.9
Mean	872	85.0	797	91.6	853	87.1
Old Adults						
200	1456	78.5	1452	87.0	1440	78.8
600	1455	80.2	1326	89.4	1449	81.1
1000	1428	80.0	1302	88.4	1406	87.3
Mean	1446	79.6	1360	88.3	1432	82.4

SOA. (3) As shown in Column 3, the presence of a semantic relationship between the prime and target produced considerable facilitation above and beyond that produced by only an episodic relationship. This effect primarily occurred at the 600-msec and 1000-msec SOAs in response latency and at the

TABLE 10
Mean Differences in Response Latency (msec) and Percent Correct for the *Related* Non-Studied Targets as a Function of Semantic and Episodic Prime-Target Relationship, SOA (msec), and Age

	SU&EU–SR&ER		*SU&EU–SU&ER*		*SR&ER–SU&ER*	
SOA	*msec*	%	*msec*	%	*msec*	%
Young Adults						
200	43	−5.1*	8	−1.6	−35	+3.5
600	88*	−7.7*	14	−1.2	−74*	+6.5*
1000	94*	−6.8*	36	−3.3	−58*	+3.5
Mean	75	−6.5	19	−2.0	−56	+4.5
Old Adults						
200	4	−8.5*	16	−0.3	12	+8.2*
600	129*	−9.2*	6	−0.9	−123*	+8.3*
1000	126*	−8.4*	22	−7.3*	−104*	+1.1
Mean	86	−8.7	15	−2.8	−72	+5.9

200-msec and 600-msec SOAs in accuracy. (4) The results again are overall similar for the young and old adults.

The ANOVA on the response latency data yielded a significant main effect of Prime Condition, $F(2, 284) = 25.48$, $MSe = 61,418$, and a significant SOA × Prime Condition interaction, $F(4, 586) = 5.09$, $MSe = 44,185$. Neither the interaction between Age and Prime Condition nor the interaction between Age, SOA and Prime Condition approached significance (both $Fs < 1.36$). The ANOVA on the accuracy data again yielded a significant main effect of Prime Condition, $F(2, 284) = 39.74$, $MSe = 0.033$. The interaction between SOA and Prime Condition approached significance, $F(4, 568) = 2.15$, $MSe = 0.031$, $p = 0.07$. Neither the Age × Prime Condition nor the Age × SOA × Prime Condition interaction approached significance (both $Fs < 1.00$).

Related versus Unrelated Non-Studied Targets. Although there was considerable consistency across age groups in the impact of prime information, it is still possible that the young and old adults responded differently to related and unrelated non-studied targets, independent of the prime information. In order to address this possibility, a mean response latency and accuracy was calculated for each subject for the related non-studied targets and the unrelated non-studied targets, collapsed across prime condition. The results from an ANOVA on the response latency data yielded a significant effect of Target Condition, $F(1, 142) = 73.10$, $MSe = 19,128$, and a significant Age × Target Condition interaction, $F(1, 142) = 4.69$, $MSe = 19,128$. The results from an ANOVA on the accuracy data yielded the precise same pattern. There was a significant main effect of Target Condition, $F(1, 142) = 299.21$, $MSe = 0.010$, and a significant Age × Target Condition interaction, $F(1, 142) = 10.01$, $MSe = 0.010$. The Age × Target Condition interaction indicated that old adults were disrupted more by a related non-studied target, compared to an unrelated non-studied target in response latency (71 msec) and in accuracy (9.6%), than the young adults (43 msec and 6.7%, respectively). Thus, although young and old adults were influenced by the primes in a very similar fashion, there was an age-related difference in their ability to reject a target word that was semantically related to a word in the studied paragraph.

Similarity in the Patterning of Means Across Age Groups

The present results clearly indicate that response latency and accuracy were modulated by the prime–target manipulations. In most cases, Prime Condition also interacted with SOA. Thus, the present manipulations clearly influenced performance. However, in none of these analyses did Age interact with either Prime Condition or Prime Condition and SOA.

In order to further address the degree of similarity in the patterning of means across the age groups, a simple correlation was calculated across the age groups for the 31 means displayed in Tables 4, 5, 7, and 9. The correlations in response latency, $r = 0.932$, $p < 0.0001$, and in accuracy, $r = 0.933$, $p < 0.0001$, were extremely high. These results highlight the fact that young and old adults were influenced by SOA and Prime Condition in a similar fashion.

In addition to the above correlations, a further attempt was made to evaluate the degree of similarity across the age groups. If young and old adults were performing in a similar fashion as a function of prime condition and its interactive effects with SOA, then one might expect a similar size correlation across two different groups of subjects that were equated on the age dimension as one finds across the two different age groups. In order to evaluate this hypothesis, two age-matched pseudo-groups were produced. Each pseudo-group included 36 young adults and 36 old adults. In this way, the two pseudo-groups were matched on the age dimension. A mean response latency and percentage correct was calculated across the 72 subjects within each pseudo-group for each of the conditions displayed in Tables 4, 5, 7, and 9. Correlations were then computed across the two age-matched pseudo-groups for both the response latency and the accuracy data. The results indicated that the correlation in response latency was slightly higher for the age-matched pseudo-groups, $r = 0.975$, than the correlation between age groups (as noted above, $r = 0.932$), but the correlation in accuracy was slightly lower for the age-matched psuedo-groups, $r = 0.923$, than the correlation between age groups (as noted above, $r = 0.933$). A Fisher's Z test of the differences between these correlations indicated that neither the difference for response latency nor that for accuracy reached significance. These results could be viewed as indicating that the degree of similarity in priming effects *between* age groups was as great as the degree of similarity *within* age groups.

GENERAL DISCUSSION

The major goal of the present study was to address age-related changes in the characteristics of spreading activation in an episodically instantiated memory network. In order to achieve this goal, a primed episodic recognition test was used that provided data concerning a wide variety of prime–target conditions. The results were quite clear. Although the old adults responded more slowly and less accurately than the young adults, there was considerable consistency in the overall pattern of priming effects.

Distance and Rate of Build-up of Activation

The major focus in the present results was the impact of prime–target distance in the episodic network and its relationship to prime–target SOA.

(1) With respect to age-related differences in the impact of distance, the present results clearly indicated that both old and young adults benefited in a similar fashion from *near* compared to *far* episodically related prime–target pairs. (2) With respect to the influence of prime–target SOA on the distance effect, the results were again quite clear. At the 200-msec SOA there was an impact of distance on accuracy for both the young and the old adults, and at the 600-msec SOA there was an impact on response latency. By the longest 1000-msec SOA, it appeared that the activation reached asymptote at a similar level for both near and far prime–target pairs.

The influence of distance and its relationship to prime–target SOA is quite important because it suggests that two characteristics of spreading activation (i.e. the impact of distance and its rate of build-up) are age-independent. In this regard, these results extend the research by Balota and Duchek (1988). In the Balota and Duchek study, age had additive effects with both SOA and prime–target strength (distance) in a *semantic* priming pronunciation study, and now the present study provides evidence that age has additive effects with both SOA and prime–target strength (distance) in an *episodic* priming recognition test.

Semantic and Episodic Activation for Studied and Non-Studied Targets

In addition to the above priming conditions, the present study provided data concerning a wide variety of prime conditions. Not only do these conditions provide data concerning age-related changes in priming effects, but they also provide important data concerning primed episodic recognition performance. For brevity, we will highlight only the major patterns.

(1) The presence of an irrelevant semantic prime–target relationship both slowed response latency and increased error rates in recognition performance for *both* studied and non-studied targets, compared to an episodically and semantically unrelated baseline (see Column 1, Table 6 , and Column 1, Table 8). Thus, it appears that subjects had difficulty ignoring irrelevant semantic activation in making their episodic "yes" and "no" decisions. It is again worth noting that in the present study prime–target semantic relationships occurred for *both* studied and non-studied targets, and therefore any semantic activation was truly irrelevant to the episodic recognition decision.

(2) The presence of only episodic activation from a prime that occurred in the studied paragraph produced little facilitation, compared to an episodically and semantically unrelated baseline. For the non-studied targets, there was little facilitation for either the unrelated non-studied targets (see Column 2, Table 8) or the related non-studied targets (see Column 2, Table 10). In addition, if one compares the performance in the episodically related near and far conditions (see Columns 1 and 2, Table 4) with performance in the episodically and semantically unrelated baseline (see Column 1, Table 5), one

can see that, if anything, there was slight evidence of inhibition (28 msec) for the episodically related conditions. This is intriguing because it suggests that there is relatively little episodic priming under the following conditions: (a) the same primes occur for both studied and non-studied targets, (b) one uses a semantically and episodically unrelated word as a baseline, and (c) subjects do not respond to the prime item. As with the impact of semantic activation, it is possible that the activation produced by the presence of an item from the studied paragraph overall distracts attention, possibly in a Stroop (1935) fashion, from making the episodic recognition decision. This might override any benefit from episodic spreading activation. Of course, the evidence for a "distance" effect noted earlier suggests that episodic spreading activation was playing some role in performance.

(3) Interestingly, when the prime–target semantic relationship was coupled with episodic activation from a prime that occurred in the studied paragraph, there was considerable facilitation in both response latency and accuracy compared to the semantically and episodically unrelated baseline (see Column 2, Table 6, and Column 1, Table 10). This effect, at least in response latency, was much larger at the 600- and 1000-msec SOAs. Hence, it appears that subjects benefited from a prime that guided memory search to the appropriate episodic memory structure when this search was coupled with a pre-existing semantic relationship between the prime and target. Moreover, the interaction with SOA suggests that the benefit of these two sources of activation takes some time to build up.

In sum, the results suggest that under the present priming conditions, the presence of only semantic information can inhibit performance, and the presence of only episodic information has relatively little impact on performance, compared to baselines that involve neither source of activation. However, when these two sources are coupled together, there is considerable benefit on performance. These synergistic effects of multiple sources of activation are quite intriguing because they suggest that only when both sources converge will they override the disruption produced by "irrelevant" sources of activation. Such superadditive effects are quite intriguing and have been reported elsewhere in the word recognition and comprehension literature (e.g. Balota & Rayner, 1983; Balota, Pollatsek, & Rayner, 1985; McClelland & O'Regan, 1981; Reder, 1983). Finally, and most importantly, the present research indicates that both young and old adults are influenced in a similar fashion from these sources of activation.

Age-Related Differences in Target Processing

Although there was considerable age constancy in the influence of the primes across the SOAs, old adults responded, on average, 585 msec slower than the young adults. Part of this slowdown is probably due to simple slowdowns in encoding and output processes (see e.g. Balota & Duchek, 1988; Strayer, Wickens, & Braune, 1987). However, differences in encoding and output processes cannot account for such a large difference, as age-related differences in lexical decision performance, a task that involves similar encoding and output processes, are only of the order of 143 msec—see e.g. Burke, White, and Diaz (1987). It is more likely that a large part of the age-related increase in response latency was due to processes involving the conscious decision regarding the episodic status of the target. In support of the notion that there were age-related differences in target processing, there was consistent evidence of Age × Target-type interactions. For example, there was a significant Age × Related vs. Unrelated Non-Studied Target interaction in both the response latency and accuracy data. Older adults, compared to younger adults, were relatively slower and less accurate in responding to related non-studied targets than unrelated non-studied targets. In addition, there were age-related differences in performance on studied and non-studied targets. There were larger differences between these two classes of items for older adults than younger adults, thereby replicating Howard et al. (1986) in accuracy, and Rabinowitz (1986) in both response latency and accuracy. Thus, although the influence of the prime type was relatively constant across age groups, the influence of target type was modulated by age.

If the large age differences were due to the processes involved in the conscious episodic recognition decisions, then what processes were being modulated by the primes? Because, in the present study, (a) the same primes occurred for *both* studied and non-studied targets and (b) subjects did not directly respond to the prime items, it is unlikely that subjects relied on the prime information in any conscious way to bias their decisions. It is more likely that the impact of the primes on accuracy and response latency was a reflection of activation processes from the prime to the target that could have influenced the perceptual recognition of the target and/or possibly have modulated the familiarity value of the target (see Atkinson & Juola, 1974). Such an impact might be considered a more stimulus driven/automatic aspect of this task compared to the actual conscious decisions regarding the target word's episodic status.

Thus, we are arguing that the episodic decisions concerning the targets were more attention-demanding than the peripheral impact of the primes. In this sense, the present results support the argument that older adults will show larger decrements in aspects of performance that are more self-directed and attention-demanding (see also Craik, 1977; Craik & Byrd, 1982; Hasher & Zacks, 1979; Howard, 1986; Rabinowitz, 1986). A recent study by Craik, Byrd, and Swanson (1987) further exemplifies this approach. These researchers addressed age-related differences across a variety of tasks. They found clear evidence that tasks that demand a considerable amount of self-initiated processing (e.g. free recall) produce larger age-related differences encoding and output processes (see e.g. Balota & Duchek, 1988; Strayer, Wickens, & Braune, 1987). However, differences in encoding and output processes cannot account for such a large difference, as age-related differences in lexical decision performance, a task that involves similar encoding and output processes, are only of the order of 143 msec—see e.g. Burke, White, and Diaz (1987). It is more likely that a large part of the age-related increase in response latency was due to processes involving the conscious decision regarding the episodic status of the target. In support of the notion that there were age-related differences in target processing, there was consistent evidence of Age × Target-type interactions. For example, there was a significant Age × Related vs. Unrelated Non-Studied Target interaction in both the response latency and accuracy data. Older adults, compared to younger adults, were relatively slower and less accurate in responding to related non-studied targets than unrelated non-studied targets. In addition, there were age-related differences in performance on studied and non-studied targets. There were larger differences between these two classes of items for older adults than younger adults, thereby replicating Howard et al. (1986) in accuracy, and Rabinowitz (1986) in both response latency and accuracy. Thus, although the influence of the prime type was relatively constant across age groups, the influence of target type was modulated by age.

If the large age differences were due to the processes involved in the conscious episodic recognition decisions, then what processes were being modulated by the primes? Because, in the present study, (a) the same primes occurred for *both* studied and non-studied targets and (b) subjects did not directly respond to the prime items, it is unlikely that subjects relied on the prime information in any conscious way to bias their decisions. It is more likely that the impact of the primes on accuracy and response latency was a reflection of activation processes from the prime to the target that could have influenced the perceptual recognition of the target and/or possibly have modulated the familiaritv value of the target (see Atkinson & Juola, 1974). Such an impact might be considered a more stimulus driven/automatic aspect of this task compared to the actual conscious decisions regarding the target word's episodic status.

Thus, we are arguing that the episodic decisions concerning the targets were more attention-demanding than the peripheral impact of the primes. In this sense, the present results support the argument that older adults will show larger decrements in aspects of performance that are more self-directed and attention-demanding (see also Craik, 1977; Craik & Byrd, 1982; Hasher & Zacks, 1979; Howard, 1986; Rabinowitz, 1986). A recent study by Craik, Byrd, and Swanson (1987) further exemplifies this approach. These researchers addressed age-related differences across a variety of tasks. They found clear evidence that tasks that demand a considerable amount of self-initiated processing (e.g. free recall) produce larger age-related differences compared to tasks that are relatively more stimulus-driven (e.g. word-generation). With respect to the present results, it is suggested that the decision regarding the episodic status of the target demands more conscious controlled self-initiated processing than the relatively peripheral influence of the prime. As noted, the present results provided considerable evidence for Age × Target-Type interactions, but no evidence of Age × Prime-Type interactions.

Conclusion

The major aim in the present study was to address age-related changes in the characteristics of spreading activation in an episodic priming task. The present results provided no evidence of age-related changes in the activation process. Thus, these results, along with the Balota and Duchek (1988) results, cast doubt on the notion that changes in the influence of network distance or the rate of activation build-up across time are underlying the observed age-related deficits in cognitive performance. In this light, these results provide further support for the growing consensus that the theoretical mechanism of spreading activation remains stable across age (see also Bowles & Poon, 1985; Burke, et al., 1987; Cerella & Fozard, 1984; Chiarello et al., 1985; Howard et al., 1986; Howard, McAndrews, & Lasaga, 1981; Rabinowitz, 1986).

There may, indeed, be an inherent difficulty in working within activation frameworks to account for age-related changes. The major paradigm (the priming task) used to address characteristics of activation processes appears to involve rather stimulus-driven components of the processing system. These are precisely the components that appear rather stable across age.

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