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Sparing Activation Processes in Older Adults

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One aspect of human cognition that is central to the understanding of cognitive performance is the process by which stimuli drive the information processing system. For example, as you are reading this text, the words themselves belong to a series of potential stimuli that direct the processing system. Other stimuli may be produced by associations to the topic being addressed, possible sounds in the room, or even previous associations to the authors of the chapter. Thus, understanding the manner in which stimuli drive the processing system is a paramount first step to understanding a fundamental aspect of the processing system.

Although several approaches to this issue have been taken, most researchers have relied on some variant of an "activation" metaphor. For example, in Morton's (1969) classic word-recognition model, "logogens" accumulate activation via featural detectors. When a given logogen reaches threshold (i.e., has received sufficient activation), the word is recognized. Posner and Snyder (1975) discuss the notion of automatic spreading activation, in which one stimulus automatically activates related concepts in memory. In fact, the explosion of interest in parallel distributed processing models relies quite heavily on the metaphor of activation (e.g., McClellend & Rumelhart, 1986).

The focus of this chapter is on the extent to which activation processes are spared in older adults. Specifically, we examine studies that vary along a distance dimension regarding the proximity of the activation produced by the retrieval cue. First we review long-term repetition priming effects. In this case, the issue is whether the earlier presentation of a stimulus will influence later operations on that same stimulus. Second, we examine semantic priming studies. In these studies, the interest is not simply in the reactivation of the same stimulus, but in

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the extent to which a *related* stimulus is preactivated through a preexisting pathway. Third, we examine episodic priming effects, for which the interest is whether the activation of one stimulus will influence the activation of a newly *associated* stimulus. Based on our review of this research, we argue that the available data from each of these experimental paradigms suggests that activation processes appear to be *relatively* spared in older adults. We then discuss some potential caveats regarding this conclusion. Finally, we discuss evidence for "where" in the processing system breakdowns appear to occur that might help explain the cognitive deficits exhibited by older adults.

I. Activation and Spreading Activation

Before turning to our review of the literature, we briefly review how the activation framework has been used to account for some basic findings in the literature. In addition, we attempt to identify some limitations of the activation framework in addressing age-related changes in cognitive performance.

A. Activation and Pattern Recognition

As noted earlier, most models of pattern recognition assume that featural detectors accumulate activation and feed higher-level representations that correspond to target patterns. For example, in the letter-recognition model by McClelland and Rumelhart (1981), feature detectors first are activated and then send activation to higher-level letter representations. These letter representations in turn send activation to higher-level word-representation units, and vice versa. McClelland and Rumelhart have detailed nicely how one might conceive of the buildup of activation across time at a given letter representation to account for letter-recognition processes across varying levels of orthographic or lexical constraint.

What are the consequences of an age-related breakdown in pattern-recognition processes? On the surface, this event may be viewed as a breakdown in activation processes. For example, in the McClelland and Rumelhart model, a simple decrease in the total amount of activation reaching a particular representation might lead to poorer identification performance. However, inferences about the activation process based on poorer identification processes must be tempered by the fact that older adults often exhibit some peripheral (sensory) breakdowns in the uptake of information (Botwinick, 1984; Madden, 1988). Thus, one must be careful to distinguish activation processes that occur after featural uptake from sensory processes that lead to featural recognition. Hence, evidence of decreased perceptual performance (e.g., letter or word recognition) may not be the strongest evidence for decreased activation processes once featural level representations are activated. We will return to this issue subsequently, when we discuss caveats regarding spared activation processes.

B. Activation and Long-Term Repetition Effects

A second approach to addressing age-related changes in activation processes is investigating long-term repetition priming effects. Such experiments do not simply address pattern recognition processes (which may or may not include age-related peripheral changes), but the impact of a previous exposure to a stimulus on later pattern recognition. In these studies, subjects typically are asked to produce an "indirect" response to a stimulus that was presented earlier. The term "indirect" means that subjects are not instructed to refer directly to the earlier study episode. For example, subjects may be asked first to read a set of words aloud. Later, they may be presented with word fragments (e.g., L–B––R–) which they are asked to complete with an acceptable word (e.g., LIBRARY). The results of such studies indicate that fragment-completion performance benefits from earlier reading the words aloud, although subjects fail to recognize the event of reading the word aloud earlier (Tulving, Schacter, & Stark, 1982).

Such long-term priming effects have received considerable attention in the literature. Some theorists have suggested that such effects represent distinct memory stores. For example, Tulving and Schacter (1990) argued that long-term repetition priming effects may reflect a presemantic perceptual representation system. Presumably, this system is quite distinct from the episodic and semantic systems. Other individuals have argued that long-term repetition priming effects reflect familiarity or perceptual fluency mechanisms (e.g., Graf & Mandler, 1984; Jacoby & Dallas, 1981). Still others argue that such effects reflect varying sensitivity of different tasks to data-driven and conceptually driven operations (e.g., Roediger, 1990). Such long-term repetition priming effects could be interpreted as reflecting the impact of activation processes during both the initial presentation of the stimulus and the later test. Therefore we will discuss the literature in this area to determine whether age-related changes in this task occur.

C. Spreading Activation

In addition to activation processes that lead to recognizing a given stimulus, considerable research investigating the spread of activation from one stimulus to a second stimulus has been done. According to the spreading activation framework, memory is organized as a network of concepts (nodes) that are interconnected by associative pathways. When part of the memory network becomes activated by internal thought or stimulus presentation, activation spreads along associative pathways to related areas of memory. This spread of activation makes concepts in related areas of memory more available for subsequent retrieval. The spreading activation framework has been used extensively in the cognitive literature to explain a variety of findings in the cognitive literature (e.g., Anderson, 1983a,b; Ratcliff & McKoon, 1981); Salthouse (1988) has used this framework to initiate a formal theory of cognitive aging.

Because the spreading activation framework has been used to account for a wide variety of cognitive tasks, researchers have argued that this framework may be particularly useful to discussing the general age-related changes in cognitive performance (Anderson, 1983a). For illustrative purposes, we describe an example of how a simple breakdown in spreading activation could account for the observed age-related differences in the use of contextual information at encoding and/or retrieval.

Consider, for example, the relevance of a simple decrease in activation to the observation that older adults do not benefit as much as younger adults from a match between encoding and retrieval contexts when those contexts involve weak associations (e.g., TRAIN–BLACK) (Rabinowitz, Craik, & Ackerman, 1982). Figure 1 displays a simplified memory network. As shown, each word is connected to a number of distinct meanings of the word (see Balota & Neely, 1980; Glanzer & Bowles, 1976; Reder, Anderson, & Bjork, 1974). Anderson (1983b) suggests that context determines the meaning of a target word that is encoded and accessed at retrieval through a simultaneous spread of activation from the context word and the target word. As the words TRAIN

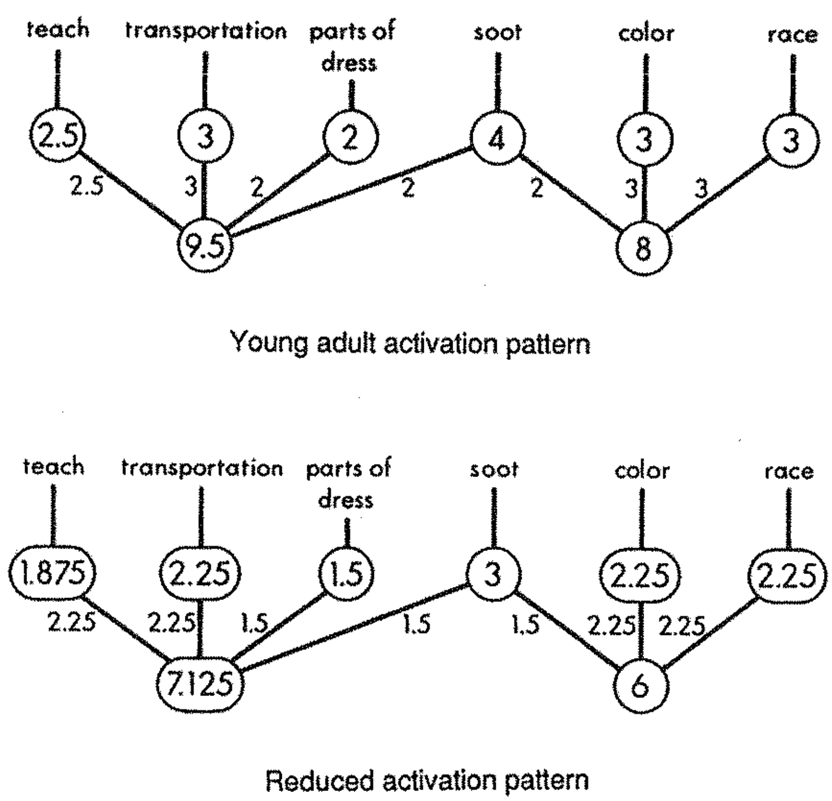

FIGURE 1

An example of how a reduction in a spreading activation mechanism might lead to decreased specificity effects at encoding. (See text for details.)

and BLACK are presented, activation spreads from both concepts and intersects at the meaning of the concept SOOT. This less dominant meaning of the word BLACK (SOOT) is more likely to be selected at encoding because of its higher activation level compared with the other meanings of the word BLACK. However, if the activation in the system is decreased by a factor of .25 (see Figure 1), then the relative difference between the activation at SOOT and the other more dominant meanings such as COLOR decreases. If one assumes a selection procedure based on probability, the decreased activation system will be more likely to select the more dominant meaning (COLOR) of the word BLACK than the less dominant meaning (SOOT). Thus, a simple decrease in activation in the system may yield decreased specificity of semantic encodings with weak associates. Such an effect would be magnified when one considers that the same selection process occurs at both encoding and retrieval.

This example illustrates one way in which changes in activation might be useful in discussing age-related changes in cognitive performance. The more important issue, however, is what the data indicate that has addressed activation processes in young and older adults directly. We attempt to address this issue by reviewing the empirical evidence on age-related changes in long-term repetition priming, semantic priming, and episodic priming tasks.

II. Long-Term Repetition Priming

As noted earlier, a substantial amount of research examining long-term repetition priming effects has been done in the past several years. The interest in this work has been nurtured by its apparent relevance to distinctions between different memory types. Long-term repetition priming effects can occur despite the fact that subjects cannot recollect consciously the earlier experience of perceiving that item. For simplicity, we will use the terms implicit and explicit memory to refer to these two classes of memory tasks. [See Schacter (1987) for a review.] Implicit memory refers to a facilitation in performance because of prior experience with the task without the conscious recollection of the earlier presentation of a stimulus. On the other hand, explicit memory refers to memory that involves the deliberate and conscious retrieval of information from the study phase, as in typical episodic recall and recognition tests. Interestingly, amnesics produce a dissociation between these two classes of memory tests, that is, they show large deficits on explicit memory tasks but little, if any, deficit on implicit memory tasks. [See Tulving and Schacter (1990) for a review.] The interest in age-related changes in implicit and explicit memory task performance has been growing.

For this discussion, implicit memory can be thought of as a situation in which the context at retrieval provides a reinstatement of the encoded stimulus, that is, the subject must make a response to the same stimulus item previously presented in the experiment. Within the activation framework described earlier, the question is whether the activation produced by the prior exposure of the item will last for an extended period of time, thereby facilitating the subsequent retrieval of that item.

Several different paradigms have been used to tap implicit task performance in older adults. For example, repetition priming tasks have been employed to address whether lexical processing is facilitated by the prior exposure of the same stimulus word in the same priming task. Mitchell, Brown, and Murphy (1990) found that older adult naming latency of pictures benefitted from prior exposure to the same pictures, even when the second presentation of the pictures occurred 21 days after the first presentation. Further, the magnitude and time course of the repetition priming effect was equivalent across young and older adults. Moscovitch (1982) reported faster lexical decisions (i.e., deciding whether a string of letters is or is not a word) after the second presentation of an item, regardless of the number of intervening items between the first and second presentation. Again, this repetition priming effect did not vary as a function of age. Similar repetition priming effects for younger and older adults have been reported for category judgments and letter detection (Rabbitt, 1982). Finally, Balota and Duchek (1991) have reported that even individuals with senile dementia of the Alzheimer type produce reliable and equivalent repetition priming in a simple naming task compared with healthy older adults.

In all the studies just mentioned not only were the same stimulus items repeated, but the same responses were required on repeated presentations of the stimulus items (e.g., naming or lexical decision). However, other experimental paradigms have required different responses to the same stimulus item in the same experimental session. For example, Light and Singh (1987) examined age differences in implicit memory in both word completion and perceptual identification tasks. In Experiments 1 and 2, subjects first were required to make vowel comparisons or pleasantness ratings for a series of words. Subjects then were given a word completion task in which the first three letters of a word were presented and subjects were asked to complete the stem with the first word that came to mind. The results indicated that more word completions were made for words seen in the prior rating tasks than for control words. Most important, no age differences in the effect were seen. In Experiment 3, subjects had to identify perceptually degraded words after the pleasantness rating and vowel comparison tasks. Again, the results indicated that more words from the previous task than control words were identified correctly and no age difference in the magnitude of the effect was seen.

Similar findings of age independence in implicit memory have been reported in other tasks. Howard (1988) reported a series of studies examining spelling bias effects for homophones. In the first phase of the study, subjects were presented a series of questions to answer (e.g., "If you were making a pizza, which kind of cheese would you grate?"), each of which included a relatively infrequently used homophone (i.e., grate). In the second phase, subjects were given a spelling test that included the previously presented homophones. The implicit measure in this task is the extent to which subjects use the previously biased spelling of the homophone (i.e., grate rather than great) in the spelling test. Howard reported equivalent spelling bias effects in younger and older adults.

In another implicit memory task, Light and Albertson (1989) had subjects first make pleasantness ratings on a list of words that contained several different embedded category exemplars (although the category names were not in this list). In the implicit task, subjects had to generate exemplars for the category names. Light and Albertson found that subjects were more likely to generate category exemplars from the previous pleasantness rating list than exemplars not seen in the previous list; no age difference in the magnitude of the priming effect was seen. Note that the retrieval context (i.e., the category names) had *not* been seen previously in the first part of the study. These findings can be interpreted to show that, because of the spread of activation from the previously seen category exemplars to the category name, the category exemplars were facilitated by the presentation of the category name during the exemplar generation task.

In all the studies just cited, repetition priming involved the activation of a pre-existing trace in memory. Howard (1988;1991) makes the distinction between implicit tasks that rely on "old" memories (implicit item memory) and those that rely on "new" memories (implicit associative memory). Implicit associative memory tasks require that a new association between previously unrelated items be created. Implicit memory performance of older adults may be expected to deteriorate under such task demands since some new learning is required. However, this does not appear to be the case. In a series of studies, Howard, Fry, and Brune (1991) examined age differences in an implicit associative memory task. Young and older subjects first were presented unrelated words for study in pairs (e.g., QUEEN–STAIRS) or in sentences (e.g., The QUEEN fell down the STAIRS.). The implicit task that followed was a word completion task that included a word and a word-stem from the studied list (e.g., QUEEN–STA___). Implicit memory is inferred if word completion performance is better on those lists that include the original pairings (e.g., QUEEN–STAIRS) than on lists that include new pairings (e.g., QUEEN–PROJECT). Howard and co-workers found equivalent implicit associative memory performance in younger and older adults. Interestingly, Schacter, Kihlstrom, Kaszniak, and Valdiserri (Chapter 13) provide converging evidence for preserved implicit priming in older adults for newly learned *nonverbal* materials. Thus, apparently no age differences occur on implicit tasks that rely on "new" memories in both verbal and nonverbal domains.

In summary, the results from the repetition priming studies clearly indicate that activation processes associated with implicit memory performance are not affected by increasing age. The prior exposure of a stimulus produces sufficient activation for an extended period of time, thereby facilitating the subsequent retrieval of that stimulus. Older adult performance is facilitated to the same extent as younger adult performance. However, when explicit memory was tested in these studies, age deficits were found consistently (Howard, 1988; Light & Albertson, 1989; Light & Singh, 1987; Mitchell et al., 1990). Thus, age differences do not exist when the context at retrieval reinstates the encoded stimulus (i.e., because the stimulus item is the same) and the task demands do not require the conscious recollection of the stimulus item. We now turn to a discussion of age differences when the retrieval context is not the same item but is *semantically* related to the stimulus item (i.e., semantic priming).

III. Semantic Priming

Spreading activation is tapped most directly in the semantic priming task. In this task, a context or prime word (e.g., CAT or POT) is presented, followed by a target string (e.g., DOG). The task is to make some response to the target string. The response is typically either a lexical decision or a naming response. The semantic priming effect refers to the finding that subjects are faster to respond to a target word (e.g., DOG) when the preceding context is semantically related (e.g., CAT) to the target than when it is semantically unrelated (e.g., POT) to the target. According to the spreading activation framework, the activation produced by the context spreads to related areas of memory, thereby making these related areas more active than in the unrelated context condition.

Several studies have investigated age-related changes in the semantic priming effect. Although the majority of these studies found no age-related changes in semantic priming and, by implication, in the retrieval mechanism of spreading activation (e.g., Bowles & Poon, 1985a; Burke, White, & Diaz, 1987; Cerella & Fozard, 1984; Chiarello, Church, & Hoyer, 1985; Howard, 1983; Howard, Lasaga, & McAndrews, 1980; Howard, McAndrews, & Lasaga, 1981; Mueller, Kausler, & Faherty, 1980), some evidence has been uncovered for age-related changes (e.g., Bowles & Poon, 1985b, Eysenck, 1975; Howard, Shaw, & Heisey, 1986; Petros, Zehr, & Chabot, 1983). Some of the disagreement in the literature could be due to the fact that the majority of the latter studies used the lexical decision task to examine semantic priming. Mounting evidence indicates that the lexical decision task is not a "pure" reflection of spreading activation, but also reflects postaccess decision strategies such as searching for a relationship between the context and target (e.g., Balota & Chumbley, 1984; Balota & Lorch, 1986; Lorch, Balota, & Stamm, 1986; Neely, 1990; Seidenberg, Waters, Sanders, & Langer, 1984; West & Stanovich, 1982). More specifically, in the lexical decision task, words can be related or unrelated to the primes but nonwords are always unrelated to the primes. Subjects can use a backward checking strategy to search for a relationship between the target and prime. If a relationship exists, the target must be a word. However, if no relationship is found between the prime and target, the target string may be a word or a nonword, a condition that would slow response latencies to unrelated targets. This confounding of prime–target relatedness with the word–nonword decision in the lexical decision task could cloud the interpretation of age differences in semantic priming tasks that use.this task. In fact, Chiarello et al. (1985) have provided evidence for age-related changes in the decision component of the lexical decision. They found age differences in the emphasis on speed and accuracy for words and nonwords. Since the pronunciation task does not involve the extra decision processes, researchers have argued that it may provide a better reflection of spreading activation processes (e.g., Balota & Lorch, 1986; Neely, 1990; West & Stanovich, 1982).

In addition to age-related changes in the size of the semantic priming effect, some of the studies mentioned also have addressed age-related changes in the *characteristics* of the underlying spreading activation mechanism. For example, Howard (1983) examined age-related differences in spreading activation and the use of context at retrieval as a function of the strength of the association between the context and target. She found similar semantic priming effects for younger and older adults with both high-dominant (e.g., BIRD–ROBIN) and low-dominant (e.g., BIRD–DUCK) prime–target pairs in the lexical decision task. Fortunately, as discussed next, a similar effect of prime–target strength also has been reported in the naming task.

Another important characteristic of spreading activation is the rate of buildup of activation across time (i.e., how quickly context affects the subsequent retrieval). Typically, this issue is addressed in studies by varying the stimulus onset asynchrony (SOA) between the prime and target. Because of general cognitive slowing with age (e.g., Myerson, Hale, Wagstaff, Poon, & Smith, 1990; Salthouse, 1985), age-related differences in the time course of activation and retrieval may be seen. This mental slowing with increased age could influence the activation process and differentially affect semantic priming effects across varying SOAs. Based on a general slowing model, one might predict that activation requires more time to build up in older adults. Thus, one might find smaller priming effects at shorter SOAs with older adults, since the effect of the context has not had enough time to build up. In general, the studies indicate that this is not the case (Balota, Black, & Cheney, 1992; Burke, White, & Diaz, 1987). The buildup of activation across time appears to be similar for younger and older adults. Interestingly, however, Howard, Heisey, and Shaw (1986) did find a significant priming effect for younger adults at a 150-msec prime–target SOA, but did not find a significant priming effect for older adults. Perhaps activation did not have sufficient time to spread within the memory network for the older adults in this short SOA. However, this explanation does not seem likely since Balota and Duchek (1988) reported a priming effect at a 200-msec SOA for older adults at a pronunciation task (see subsequent description). Perhaps the age difference reported by Howard and colleagues is a result of the lexical decision task used in that study. As noted earlier, since the lexical decision task involves postaccess processes, age differences in such processes rather than age differences in spreading activation may underlie this finding. We focus now on a study that used the naming task to investigate the characteristics of the spreading activation process.

Balota and Duchek (1988) reported a study designed to examine age-related changes in (1) the rate of buildup of activation across time and (2) the underlying strength of the relationship between the context and the target. Activation may build up very quickly at a given node or may take time to build up (see Lorch, 1982; Ratcliff & McKoon, 1981). Further, the rate of buildup of activation may depend on the strength of the relationship between the context and the target, that is, a strong pre-existing relationship between the context and the target may cause activation to build up immediately. On the other hand, a weak relationship between the context and the target may allow activation to build up at a much slower rate.

Balota and Duchek (1988) used a paradigm developed by Lorch (1982) to address age-related changes in the activation process. Participants in a semantic priming pronunciation task consisted of 60 young and 60 older adults. Subjects were presented high-strength prime–target pairs (e.g., ANIMAL–DOG) and low-strength prime–target pairs (e.g., ANIMAL–SWAN). A neutral baseline condition was included also (e.g., BLANK–DOG or BLANK–SWAN) to provide a measure of the facilitation caused by the related prime conditions. In addition, the SOA between context and target was varied between 200 and 800 msec in 150-msec increments to examine the rate of buildup of activation across time.

The results of this study are quite straightforward. First, as seen in Figure 2, overall response latency was slower for the older adults than for the younger adults. More importantly, however, the overall pattern of data is remarkably similar for older and younger adults, that is, response latency is fastest for the high-strength targets, compared with the low-strength and neutral targets. Further, this difference is largest at the long SOAs for both age groups. The mean facilitation effects (i.e., the differences between the neutral and the corresponding related prime conditions) are displayed in Figure 3. Again, evidently older and younger adults show similar patterns of data. The high-strength targets produced a greater facilitation effect than the low-strength targets, and these effects build up across time. In fact, older adults appear to produce a slightly larger priming effect and a slightly earlier buildup of activation than younger adults, possibly suggesting that context has a greater beneficial impact on the retrieval system of older adults. Clearly, the Balota and Duchek study (1988) indicates that the rate of buildup of activation across time and across varying strengths of prime–target relationships appears to be spared by the aging process.

Of course, age differences in the rate of buildup of activation actually may exist, that may have been obtained if Balota and Duchek had selected SOAs between the 200-msec SOA and the 350-msec SOA (see Chapter 12). However,

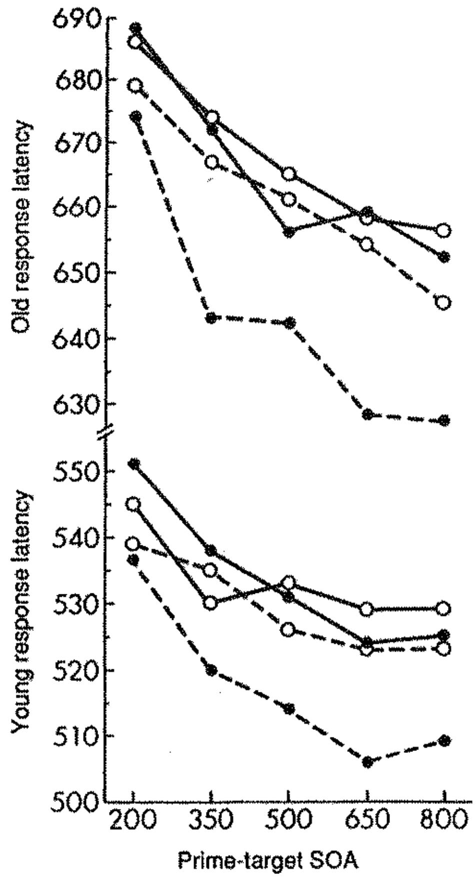

FIGURE 2

Mean response latency in the semantic priming task as a function of age, prime relatedness (related, ●; neutral, ○), strength (high strength, ----; low strength,———), and stimulus onset asynchrony (SOA).

this result appears to be relatively unlikely since no significant priming effect was observed for either age group at the shortest SOA and, if any change was seen, priming effect was larger for the older group at the 350-msec SOA. In fact, as shown in Figure 3, the data appear to indicate a larger increase in the buildup of activation for the older adults than for the younger adults between the 200-msec and 350-msec SOAs.

Bowles (Chapter 12) argues that the interpretation of no age differences in the Balota and Duchek (1988) study is somewhat weakened by the fact that neither age group produced a significant priming effect at the 200-msec SOA. Note that the relatively small semantic priming effects reported in the Balota and Duchek study are typical of category priming in the naming task. As mentioned earlier, the naming task has been viewed as a relatively pure measure of activation from the prime to the target without contamination by postaccess decision mechanisms. In fact, the size of the priming effects reported by Balota and Duchek are quite consistent with the size of the priming effects reported by Lupker (1984)

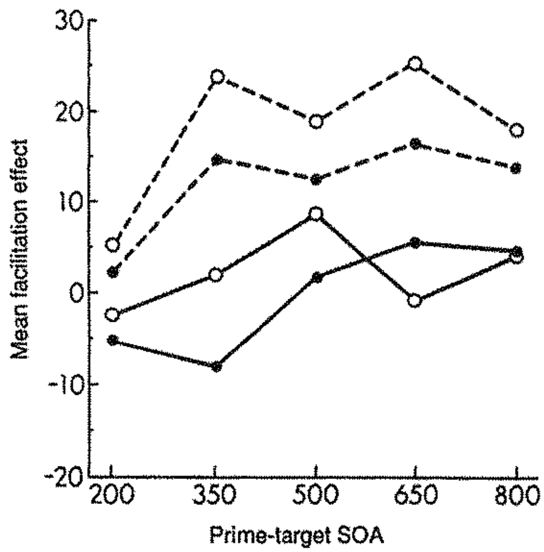

FIGURE 3

Mean facilitation effect (neutral minus related prime condition) in the semantic priming task as a function of age (young, ●; old, ○), strength, (high strength, ---; low strength, ——), and stimulus onset asynchrony (SOA).

and Seidenberg et al. (1984). Moreover, the fact that the priming effect appears to increase at a slightly greater rate for the older adults than for the younger adults between the 200-msec and the 350-msec SOA suggests that the lack of a reliable priming effect at the shortest SOA for either group of subjects is not a serious concern.

In summary, no age differences exist in the extent to which context influences the retrieval (via spreading activation) of related information in semantic priming tasks. Further, the presentation of context actually may benefit the retrieval system of older adults *slightly more* than that of younger adults. (This latter issue is addressed again subsequently.) In this light, note that McGlinchey-Berrath and Milberg (Chapter 16) report normal or larger semantic priming effects in patients with Alzheimer's disease (also see Balota & Duchek, 1991). We now turn to a discussion of age differences when the retrieval context produces activation in an "episodically instantiated" memory network.

IV. Episodic Priming

The characteristics of spreading activation, as reflected in a semantic priming task, may not change as a function of age because of age-related changes in the strength of the pre-existing relationship between the context and the target item.

Age differences may be masked by the more extensive previous experience of older adults in using context to retrieve the same information, that is, with age these pre-existing relationships in memory actually may become stronger. Thus, the rate in which activation spreads within the memory system perhaps only appears to be age independent, as reflected by results from the semantic priming task.

Episodic priming tasks have been used to examine the manner in which context affects the activation and retrieval of newly learned information. Since older adults exhibit a marked memory deficit in episodic memory tasks (Burke & Light, 1981; Kausler, 1982), examining the retrieval mechanism of spreading activation for episodic memories is important. This examination can be accomplished by "building" a memory network in the context of the experimental setting so one can manipulate the organization and strength of the relationships in the memory structure.

Balota and Duchek (1989) examined age differences in an episodic priming task that closely followed a paradigm used by McKoon and Ratcliff (1979). In this task, subjects studied paragraphs such as the one displayed in Figure 4. Each paragraph consisted of five sentences in which the object of one sentence (e.g., CARPET) is the subject of the following sentence. This paragraph can be represented as a propositional network, as displayed in Figure 4 (Anderson, 1983a; McKoon & Ratcliff, 1979). Because of the shared structure of the sentences within the paragraph, a linear representation can be created.

Once a memory representation is assumed, examining how the presentation of context influences the retrieval of newly learned associations in an episodic network is possible. In an episodic priming task, a context or prime word (e.g., WORKMAN) is presented, followed by a target word (e.g., CARPET). The task is to read the context silently and decide as quickly and as accurately as possible whether or not the target word was in the studied paragraph. If the context word (e.g., WORKMAN) was in the paragraph, activation will spread throughout the memory network, thereby facilitating the episodic recognition of the target item (e.g., CARPET) relative to the condition of priming with a context word (e.g., LION) that was not in the studied paragraph.

Several episodic priming studies compare young and older adults (Howard, 1985,1988; Howard et al., 1986; Rabinowitz, 1986). In general, the results of these studies indicated that the episodic context facilitated the recognition of the target for both younger and older adults to the same extent. However, some evidence for age-related changes was seen (1) when subjects were given only one study period, (2) for backward associations, and (3) for "between" propositional representations. [See Balota & Duchek (1989) for a full discussion of these findings.]

We attempted to examine further the following characteristics of spreading activation and subsequent retrieval in an episodic network: (1) the rate of buildup of activation across time and (2) the "strength" of the underlying relationship

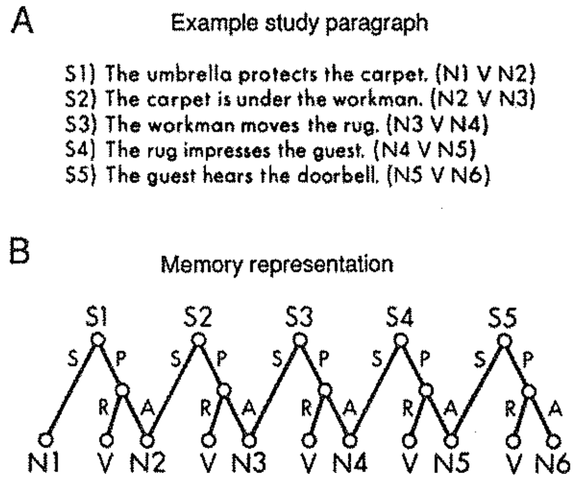

FIGURE 4

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

between the context and the target. Thus, this study was an extension of the Balota and Duchek (1988) *semantic* priming experiment. To address the rate of buildup of activation across time, the SOA between the primes and targets was 200 msec, 600 msec, or 1000 msec. To address the influence of the "strength" of the relationship between the context and target, we varied the prime–target "distance" traversed by the activation in the memory network. More specifically, prime–target pairs were either "near" (e.g., WORKMAN–CARPET; see Figure 4) or "far" (e.g., GUEST–CARPET; see Figure 4). In addition, comparisons across several types of prime–target relationships were addressed. [See Balota & Duchek (1989) for a more complete description.] Primes and targets at recognition could be related episodically, semantically, or both.

The results indicated that episodic recognition was influenced similarly by the prime–target relationships for both young and older adults. As can be seen in Table 1, the "near episodic" context produced faster recognition latencies and more accurate responses than the "far episodic" context for the young and the older adults. Also, no age difference in the impact of SOA on this distance effect was seen. Only the 600-msec SOA produced a significant distance effect in recognition latencies; the 200-msec SOA produced a significant distance effect in accuracy. Further, no interactions with age occurred across any of the 33 prime–target conditions included in this study.

Thus, this study replicated the Balota and Duchek (1988) semantic priming study, because the rate of activation buildup and the influence of the strength of the underlying relationship between the context and the target were shown to be

TABLE 1
Mean Response Latency and Percentage Correct as a Function of Near and Far Episodically Related Primes, SOA, and Age

SOA (msec)	Near		Far		Far − Near	
	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

[a]With permission from Balota & Duchek (1991).
*$p < .05$.

age independent. Further, no age differences were seen in the activation process across a wide variety of context–target relationships. Noted also that, although the retrieval mechanism of spreading activation in an episodic memory structure is not affected by age, age differences in more general memory performance did exist. For example, older adults studied the paragraphs for a longer period of time, were slower in making their episodic recognition decision, and were less accurate in their decisions.

Hasher and Zacks (1988) have reported a similar pattern in an episodic priming task. Again, subjects were presented sets of sentences and had to perform a recognition task on nouns from the preceding sentences. A prime word was presented with the target (i.e., test) word at 300- or 1000-msec SOAs. In addition, primes and targets were either from the same sentence (within prime–target condition) or from difference sentences in the set (between prime–target condition). The results indicated that older and younger subjects showed equivalent priming effects across all conditions.

In summary, the results from the work on the characteristics of activation in an episodically instantiated memory network converge on the notion that no major differences in the activation mechanism occur, even across newly instantiated associations.

V. Spared Activation: Summary, Caveat, and Relevance to Episodic Memory Breakdowns

A. Summary

The purpose of this chapter was to assess the extent to which context influences the retrieval of related information in older adults. Specifically, we addressed this issue by examining the characteristics of activation and spreading activation. In this way, the relationship between the context and the to-be-retrieved information could be examined. Three different context–target retrieval paradigms were discussed: repetition priming, semantic priming, and episodic priming.

First, repetition priming represents a retrieval situation in which the context at retrieval directly reinstates the encoded stimulus. No age differences have been reported across several different implicit memory paradigms (see Howard, 1988, for a review) that tap both the activation of pre-existing traces and the activation of newly learned associations. Thus, the prior exposure of a stimulus item produces sufficient activation for an extended period of time, thereby facilitating subsequent retrieval of that same stimulus item. The extent to which performance is facilitated is the same for young and older adults.

Second, the semantic priming paradigm represents a retrieval situation in which the context at retrieval is *not* the same as the encoded stimulus, but the context is *semantically* related to the stimulus. Once again, generally no age differences are reported across a variety of semantic priming paradigms (e.g., Balota & Duchek, 1988; Bowles & Poon, 1985a; Burke et al., 1987; Cerella & Fozard, 1984; Chiarello et al., 1985; Howard et al., 1981). Moreover, the results of the Balota and Duchek (1988) study indicate that the specific characteristics of the rate of buildup of activation across time and the influence of the strength of the prime–target relationship also appear to be age independent.

Finally, episodic priming represents a retrieval situation in which the context at retrieval is *not* semantically related to the target stimulus, but is *episodically* related to the target stimulus. As in the semantic priming paradigm, no age differences occur in the influence of context on the retrieval of newly learned associations in episodic priming tasks (Howard et al., 1986; Rabinowitz, 1986). Again, Balota and Duchek (1989) have demonstrated that the characteristics of the rate of activation buildup, and of the distance activation must travel in an episodically instantiated memory structure, appear to be age independent.

B. Caveat: Spared Activation or Compensation

Although the data reviewed in the chapter primarily converge on the assumption that the activation and spreading activation processes are relatively spared from age-related changes, an important caveat must be addressed. This caveat is prompted by the observation that some evidence exists for *larger* semantic priming effects in older adults than in younger adults across a number of studies. [See meta-analyses by Laver & Burke (1990) and Myerson, Ferraro, Hale, and Lima (1992).] The tendency for larger priming effects in older adults may result from a type of compensatory strategy (Balota & Duchek, 1988; Bowles & Poon, 1985). Specifically, considerable data are available that indicate that, if word recognition is slowed via a stimulus degradation manipulation, the context effect increases (e.g., Becker & Killion, 1977; Stanovich & West, 1983). If lexical access (i.e., word recognition) is slower in older adults (see Balota & Duchek, 1988), then an increased reliance on and, thus, benefit from context may occur (see also Madden, 1988). Very simply, older adults may be more likely to rely on context to compensate for any deficit in simple word recognition processes (see Stanovich & West, 1983). Interestingly, Kemper and Anagnopoulos (Chapter 19) and Tun and Wingfield (Chapter 17) argue for a compensatory model of discourse comprehension in which linguistic context serves to compensate age-related deficits in lower-order sensory processes and even in breakdowns in syntactic processing. Thus, older adults appear to rely on compensatory processes at a number of different levels in the processing system.

The notion of compensatory processing in older adults, however, creates a caveat for the conclusion that minimal age-related changes are associated with the spreading activation mechanism. Individual studies have argued that the equivalent, or slightly larger, semantic priming effects for younger and older adults reflect a sparing of the activation process with age. However, the empirical finding of equal priming effects across age may reflect an age-related compensatory mechanism rather than an age-related *sparing* of the activation process, that is, reliance on context by older adults may be increased because of breakdowns in the uptake of featural information. Thus, the activation process as reflected by priming may only *appear* to be age independent. Moreover, because similar lexical access processes often are involved in repetition priming paradigms and episodic priming paradigms, these paradigms also may be affected by compensatory strategies.

Balota and Duchek (1988) attempted to address the notion that older adults may produce equivalent, or slightly larger, priming effects because of compensatory processing due to a breakdown in lexical access processes. In pursuit of this goal, they employed a delayed-naming task (see Balota & Chumbley, 1984). In this task, subjects are presented a word and are asked to name the word aloud in response to a cue (parentheses flanking the word) that is presented after varying delays from the word onset. In the Balota and Duchek study, the cue delays varied between 150 msec and 1200 msec in 150-msec increments. Balota and Duchek argued that performance in this task can be used as an estimate of lexical access processes. Specifically, at short cue delays, subjects should still be engaged in word recognition processes when the cue is presented whereas, at longer cue delays, word recognition processes should be complete and response latency should reflect primarily *simple* naming response latency to the cue. If older adults are slower in these earlier processes than younger adults, they should benefit more from a cue delay than the younger adults. The results of this study indicated that older adults did benefit more from relatively short cue delays than younger adults, thereby suggesting an age-related change in word recognition processes. However, two points must be noted. First, even at the longest delays at which response latencies were asymptotic for young and older adults, a 100-msec difference in overall response latency was seen. This difference most likely reflects a difference in output processes after lexical access has taken place. Comparing this difference to the overall 130-msec age-related difference in on-line naming in the semantic priming task, one obtains an estimated 30-msec difference in age-related lexical access processes. Admittedly, this value can be used only as a global estimate. However, this relatively small difference in access times does not appear to be sufficient to account for the finding that, as shown in Figure 2, the rate of buildup of activation in older adults is actually slightly larger between the 200-msec and 350-msec delays. Thus, although some compensation in older adults may occur, we do not believe that the available data indicate that the evidence for such compensation is great enough to suggest age-related changes in the spreading activation process. The relatively small influences of age on lexical access processes (see also Cerella & Fozard, 1984) probably account for the slightly larger priming effects that are found occasionally. Clearly, however, future work is necessary to separate fully the activation mechanisms from the compensatory effects that are caused by breakdown in access processes.

Note that the tendency for larger semantic priming effects in older adults compared with younger adults also has been interpreted to reflect a global slowing process (see Myerson, Ferraro, Hale, & Lima, 1992; Chapter 5). Although such an argument may account for some aspects of some studies (e.g., Balota & Duchek, 1988), this approach would appear to have particular difficulty accounting for other age-related priming effects in the literature. For example, Balota, Black, and Cheney (1992) report reliably *smaller* priming effects in older adults than in compared to younger adults at the longest SOAs in a naming task (Experiments 1 and 3). The thrust of this study was isolating spreading activation mechanisms from attentional direction mechanisms. These investigators argue that the attentional mechanism, primarily tapped at the long prime–target SOAs, produces some breakdown whereas the spreading activation, primarily tapped at the short prime–target SOAs, does not. The important point for this discussion is that age-related changes appear to be more likely to occur in the attentional component of priming than in the automatic component. Such a dissociation is difficult to account for with a general slowing account of semantic priming effects.

C. Relevance to Episodic Memory Breakdowns

Although evidence that the activation process is spared with age appears to be consistent, clear evidence exists of age deficits in episodic memory performances that involve the use of context at retrieval, for example, cued recall tasks. For example, in a levels-of-processing task, Duchek (1984) found that the memory performance of older adults was enhanced when a match was formed between an encoding and retrieval cue, compared with a mismatch in these cues. More importantly, however, older adults showed poorer overall memory performance than younger adults, especially when a match occurred between a semantic encoding and a semantic retrieval context. Thus, older adults did not benefit as much as younger adults from a match between semantic context at encoding and at retrieval. Why older adults show poorer memory performance in some situations, although the retrieval mechanism of spreading activation remains stable with age, is unclear.

One way to resolve this apparent dilemma is to refer to Craik's "functional" view of age-related memory deficits (Craik, 1986; Craik, Byrd, & Swanson, 1987). Craik has argued that age-related memory deficits are predicted well by the extent to which a given task demands self-directed or initiated retrieval processing. When tasks provide support for retrieval (e.g., recognition tasks and most implicit memory tasks), age-related memory differences are minimized. Now consider this framework with respect to priming studies. In the priming tasks described, the context (i.e., the prime) directly guides retrieval through a spread of activation. In fact, in most cases the subject is not required to respond to the prime at all and, therefore, is not required to self-initiate retrieval processes based on prime information. The prime, in some sense, passively activates relevant memory representations. Hence, performance in such tasks is more stimulus driven than self-initiated. Therefore, as predicted by Craik, age-related differences are minimized.

The distinction between stimulus-driven and self-initiated task demands is supported by the results of the episodic priming task. In the episodic priming task, the prime presumably produces a more passive stimulus drive impact, but the subject is requested to make a self-directed decision about the presence of the target in the earlier studied materials. In the Balota and Duchek (1989) study, no evidence was found of any age-related changes in the impact of the prime on target processing across 31 different prime–target conditions. However, clear age differences were found in the self-directed target processing, independent of prime information. As previously described, older adults were both slower and less accurate in their episodic recognition decisions. Further, older adults were slower and less accurate when responding to related nonstudied targets than to unrelated nonstudied targets. Also, age differences in recognition accuracy for studied and nonstudied targets were seen (see also Howard et al., 1986). Thus, the more attention-demanding or self-initiating aspects of the task were affected by age, whereas the more stimulus-driven impact of the context (or primes) on target recognition was spared by age.

Why does context benefit the retrieval system of older adults? One function that context may serve is providing environmental support that guides processing. The reason this support may be *more* important for older adults is that their processing may be more likely to be influenced by interference from irrelevant stimulation. Evidence from studies on problem solving suggests that older adults have more difficulty inhibiting irrelevant information than do younger adults (Botwinick, 1984). In fact, Hasher and Zacks (1988) have proposed a theoretical account of age-related differences in comprehension processes in which they argue that older adult problems in comprehension stem from a breakdown in inhibitory mechanisms in short-term memory. If a breakdown occurs in the ability to inhibit irrelevant information with age, then context would keep processing "on track" and, therefore, benefit older adult performance *more* than that of younger adults.

The study by Balota, Black, and Cheney (1992) is noteworthy here because this study provides some support for the notion that context is quite helpful in keeping self-directed processing by older adults on track. Balota and colleagues used the paradigm developed by Neely (1977) to separate age-related changes in the relatedness effect and the expectancy effect across different SOAs in a simple naming task. As noted earlier, the results indicated that, although no age-related differences were seen in the relatedness effect across SOAs (consistent with the studies reviewed earlier), some evidence of a change in the expectancy effect across SOAs was found. In particular, younger adults produced increasing expectancy effects across SOAs whereas, in the first and third studies of that report, older adults actually showed a decreasing expectancy effect between the intermediate SOA and the longest SOA. Interestingly, in both these experiments, the prime was only visually available for 200 msec of the functional SOA; the remaining duration of the SOA involving a blank screen. For example, at the 1750-msec SOA, the prime was presented for 200 msec, followed by a 1550-msec blank screen. Balota and co-workers argued that the decreased expectancy effect at the longest SOA in the older adults may be caused by an inability to inhibit irrelevant information when the prime is not visually available throughout the SOA. In fact, Balota and colleagues demonstrated in their second experiment that, if the prime is available throughout all but 50 msec of the SOA, the age-related differences in the change of the expectancy effect across SOAs were eliminated.

VI. Conclusions

This chapter indicates that, as long as the influence of prime information produces activation that reflects more stimulus-driven components of processing, relatively little evidence of age-related changes in processing is seen. However, when the prime provides information that involves self-directed involvement of attention, age-related changes in performance are found. This finding may be related to a general failure to inhibit irrelevant information in older adults, and also may be related to general breakdowns in memory performance when self-initiated processing is demanded. Clearly, a major step that has yet to be taken within the activation framework is specifying how activation processes influence more self-directed processing (see Balota, 1983). This next step is particularly important in the cognitive aging literature because results such as those reviewed in this chapter converge on the notion that the activation processes tied to the stimulus are relatively spared by the aging process, but the self-initiated processing that occurs after and/or with these activation processes seems to be relatively impaired. [See Charness (1988) for similar arguments.]

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