CHAPTER 6

Spreading Activation and Arousal of False Memories

Henry L. Roediger III
David A. Balota
Jason M. Watson

To understand how the mind works, one must understand associative processing. This idea is as old as Aristotle's first theories of mind, in which he speculated about the factors that create mental associations (contiguity, similarity, contrast). Succeeding generations of scholars and researchers have repeatedly affirmed, both in their theories and in experimental research, that the mind is an exquisitely tuned device for holding associative information. This theme permeates modern cognitive psychology. Activation of a concept in episodic or semantic memory is believed to spread among neighboring concepts, partially arousing them, and thereby influencing mental life.

The associative effect of one concept on another has been studied in many paradigms in cognitive psychology. For example, in a standard semantic priming paradigm (e.g., Neely, 1977, 1991; see also Neely & Kahan, chapter 5, this volume), the speed of deciding that a letter string (*doctor*) is a word is increased if it has been preceded by an associatively related word (*nurse*) relative to an unrelated word (*house*). The basic explanation is that activation of *nurse* spreads through an associative–semantic network, thereby partially activating the related word *doctor* so that it can be identified faster. Similarly, in the false-recognition paradigm used by Underwood (1965), the presence of a word such as *table* in a list increased false recognition of a related word such as *chair*, relative to unrelated concepts such as *screen*. A straightforward interpretation of this finding is that presentation of the word *table* may have aroused an implicit associative response, as Underwood called it, to *chair* when *table* was encoded. When *chair* later was presented for a recognition

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decision, its partial activation earlier caused it to be falsely recognized. Spreading activation through associative–semantic networks may be responsible for both phenomena.

Although associative processes are routinely invoked to explain both semantic priming phenomena and false-recognition phenomena, systematic examination of possible commonalities between these two areas of inquiry has not been carried out. One purpose of this chapter is to begin such exploration of the connections between activation processes within an interrelated network and the development of false memories. In pursuit of this goal, we first provide a brief review of the use of the spreading activation metaphor in explaining phenomena beyond simple semantic priming effects.

Beyond Semantic Priming and Spreading Activation

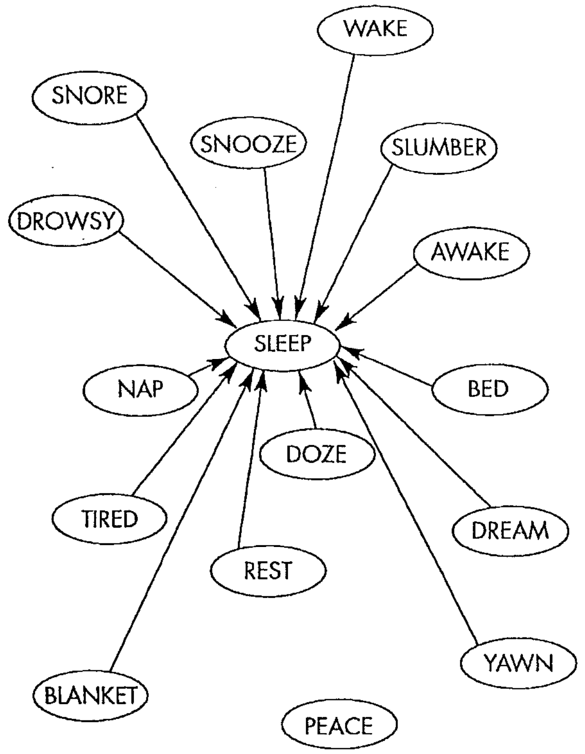
As Anderson (1983) pointed out, the priming paradigm is ideally suited to investigating the spreading activation mechanism. Hence, we briefly review evidence concerning some of the core aspects of spreading activation from a series of semantic and episodic priming tasks. The findings indicate that (a) there are clear similarities across semantic and episodic tasks, (b) activation spreads across multiple links within both episodic and semantic networks, and (c) activation summates on concepts in memory. After this review, we then turn to the relevance of this mechanism for the study of false memories.

The metaphor of spreading activation within an interrelated network of associated concepts (see Figure 6.1) has been central in models of letter processing (McClelland & Rumelhart, 1981), semantic priming (Collins & Loftus, 1975), speech production (Dell, 1986), and memory and problem solving (e.g., Anderson, 1976). In fact, this mechanism is the major retrieval process in both the human associative memory and the adaptive control of thought models developed by Anderson (e.g., 1976; Anderson & Bower, 1973) and is the primary retrieval mechanism invoked in connectionist models (see McClelland & Rumelhart, 1986). The widespread appeal of this framework is that it (a) has potential quantitative tractability, (b) relies on straightforward associative learning principles, and (c) has at least some similarity to the notion of neural connections within interrelated ensembles of neurons.

Although the metaphor of spreading activation has been widely used, one might question the utility of such a spreading activation process beyond simple semantic priming paradigms. All learning systems that have been studied are sensitive to associative co-occurrence. If this is the case, then one might ask if this framework provides explanatory power above and beyond conditioning principles that have been well established in other arenas. The verbal learning and memory tradition (elegantly reviewed in chapter 8 of Crowder, 1976) has clearly established the importance of associative information in paired-associate paradigms. Again, what

FIGURE 6.1

Hypothetical semantic network of concepts related to sleep.



are the novel predictions of the spreading activation framework? We now briefly review some evidence suggesting that the same spreading activation processes empirically documented in semantic priming paradigms extend to some standard effects observed in the episodic memory literature. This converging evidence provides the foundation for extending the spreading activation metaphor to the study of false memories.

Spacing by Retention Interval Interaction

Crowder (1976) argued that one of the more powerful ways to dissociate two memory systems or processes is to find a variable that affects the two different memory processes in opposite directions, that is, a variant of the functional dissociation approach. Many such variables exist, but one that is particularly intriguing are [illegible]om an experiment by Peterson, Wampler, Kirkpatrick, and Saltzman (1963) They showed that the spaced study of paired associates provides a benefit over massed study in a delayed testing situation (the usual spacing effect). However, they also showed that on an immediate test, the opposite effect emerges—massed repetition provides better retention than spaced repetition. At Yale University, this effect became known as the "Peterson paradox," owing to Endel Tulving, because of the paradoxical outcome that spacing can have opposing effects on memory performance depending on the delay between the second presentation and the test. Balota, Duchek, and Paulin (1989) replicated these surprising effects in both younger and older adults. Crowder (1976, p. 294) viewed this finding particularly difficult to accommodate within the standard models of memory and appealed to Estes's (1955) stimulus sampling model as one way to account for this interaction.

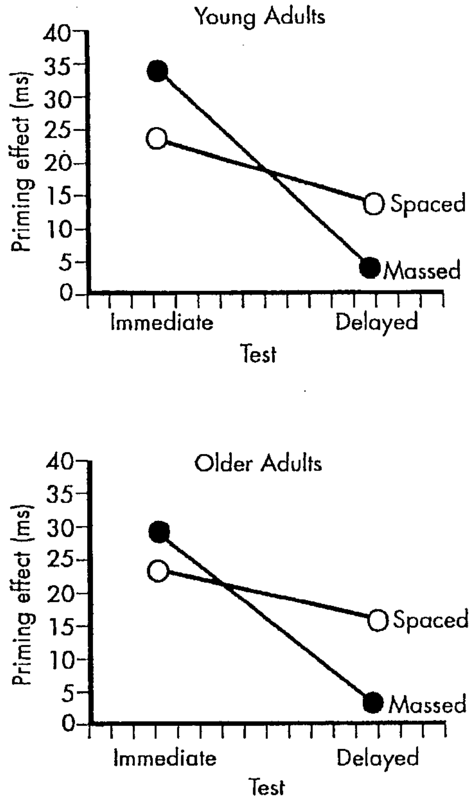
Can one find a similar Spacing × Retention Interval interaction in a priming situation, or is this interaction limited to episodic memory performance? If one could find a similar pattern in a priming paradigm, then this would increase the general applicability of the spreading activation metaphor in accommodating how information becomes accessible in memory. This was the goal of a study by Spieler and Balota (1996). This experiment was modeled after the Peterson et al. (1963) study with the subjects' simple task being to name two semantically unrelated words on each of 500 trials, with some pairs repeated. Spieler and Balota manipulated both the spacing between the repeated word pairs and the distance (intervening items or time) between the last presentation and the test trial. The speed to name the second word when it was paired with the same earlier presented word, compared with when it was paired with a new word, across repetitions was the measure of activation from the prime to the target. The results of this study are clear and are shown in Figure 6.2: The Spacing × Retention Interval interaction did occur in a priming paradigm in which episodic memory retrieval is unlikely to be involved. Thus, the priming paradigm does show a parallel effect to a powerful episodic memory phenomenon under conditions that minimize strategic attentional operations. As Crowder (1976, chapter 9) emphasized, the Spacing × Retention Interval interaction is a fundamental aspect of memory performance and permeates both human and animal learning studies.

Does Activation Really "Spread" Within the Memory Network?

Of course, all that we have demonstrated so far is that an intriguing finding originally obtained in standard paired-associate studies (the Spacing × Retention Interval interaction) can be extended to an automatic type of episodic priming paradigm. However, if the spreading activation metaphor has real value, then one should be able to find that activation does not simply influence a directly related concept but

FIGURE 6.2

Mean episodic priming effects (unrelated prime – repeated prime) in speeded naming performance as a function of retention interval and spacing. Data from Spieler and Balota (1996).



also extends beyond directly related concepts to more distant concepts in memory. This is a relatively difficult issue to explore because there is often a weak relation between more distance concepts in memory. The strategy researchers have used to answer this question is to construct triads of words in which two words that are themselves unrelated are related to a third word. Consider the words *lion–tiger–stripes*. The words *lion* and *stripes* are only related through the mediator *tiger*. If one finds priming from *lion* to *stripes*, then one would have evidence for activation spreading multiple steps within the memory network.

The first person to conduct such research was de Groot (1983), and her initial attempt to find such mediated or two-step priming failed to provide any evidence for priming from concepts such as *lion* to *stripes* using the lexical decision task. de Groot viewed this null outcome as a problem for the spreading activation metaphor. However, Balota and Lorch (1986) argued that de Groot's failure to find such multiple step activation may have been due to her use of the lexical decision task, which encourages backward checking processes. That is, evidence exists that subjects check back for a relation to the prime word when they respond to the target word (see Neely, 1991), and this fact may have minimized the sensitivity to mediated priming effects. Specifically, if subjects checked for a relation between *stripes* and *lion*, they usually would fail to find one (especially at a 250-ms stimulus onset asynchrony), and hence the words may be treated as an unrelated pair. Balota and Lorch switched the dependent measure to speeded naming in which any postlexical checking process is minimized. It is interesting to note that in this study, there was clear evidence for mediated priming. In a later study, McNamara and Altarriba (1988) also found evidence for multiple step activation processes in a version of the lexical decision task that minimizes the backward postlexical check process. They found that activation not only spreads two steps but actually can spread three steps, for example, from *mane* to *lion* to *tiger* to *stripes*.

Of course, one might again question whether the phenomena produced in a semantic memory task would also extend to an episodic memory task. Specifically, can one find multiple step activation processes within an episodically instantiated memory network? To pursue this issue, Balota and Duchek (1989) asked participants to study a set of paragraphs that were linked such that the predicate of sentence N was the subject of sentence $N + 1$. Examples of such sentences and the corresponding network (see Ratcliff & McKoon, 1981) are displayed in Figure 6.3. After the sentences are stored in memory, one can then test episodic memory recognition for a given target word when it is briefly primed by a word that varies in distance from that target. For example, the target word *guest* could be primed by a word close within the network (e.g., *rug*) or a word more distant within the network (e.g., *workman*). In the Balota and Duchek experiment, the primes were presented for varying durations (200, 600, or 1,000 ms), and the subjects were asked to simply make speeded yes–no episodic recognition decisions only on the target. Interestingly, there was priming compared with a neutral baseline (the word *blank*) for both the near and the distant conditions, but the distant condition produced less priming (50 ms) than did the near condition (72 ms). Thus, the metaphor of spreading activation across multiple nodes within a memory network occurs not only in semantic memory networks but also in networks established by recent episodic encodings and with an episodic recognition task.

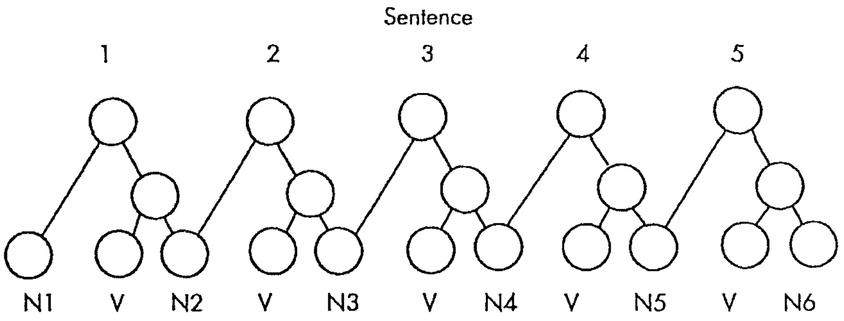
Does Activation Summate?

If the activation metaphor is useful in accounting for encoding and retrieval processes, one should find evidence that multiple sources of activation produce greater priming

FIGURE 6.3

Propositional network and example paragraph for simple linear networks.

1. The umbrella protects the carpet.
2. The carpet is under the workman.
3 The workman moves the rug.
4. The rug impresses the guest.
5. *The guest hears the doorbell.*



than a single source of activation. Balota and Paul (1996) identified three theoretically intriguing ways that activation might combine at a particular concept in memory. The first is an underadditive pattern in which two sources of activation may provide less effect than the sum of the individual sources. For example, if a single prime produces a near asymptotic level of activation, an additional prime can no longer boost activation beyond this asymptote. The second pattern is simple additivity in which the influence of two sources of priming may add together, so that the combined effect would be their sum. This seems to be the implicit assumption of most activation-based models, although this issue is typically not addressed in the models. The third interesting pattern is superadditivity in which the sum of the individual primes is greater than their simple additive effects. Superadditivity of priming might be expected if multiple sources of activation converge and direct conscious processing to the highly activated node. If neither prime alone would do so, but their combination does, an overadditive priming effect would occur.

Although the extent to which multiple sources of activation combine is a seemingly straightforward issue, this topic has received relatively little attention in the semantic priming literature (see Balota & Paul, 1996; Brodeur & Lupker, 1994; and Schmidt, 1976). The real trick in this research is to minimize the influence of the first prime on the second prime, which often occurs because three words are likely to be interrelated (e.g., *doctor–nurse–patient*). Balota and Paul attempted to avoid this problem by developing a multiple prime paradigm in which primes were unrelated to each other but converged on a target word. Examples of the four critical conditions are shown in Table 6.1: related–related, related–unrelated, unrelated–related, and unrelated–unrelated. Also note that in the related–related (*lion–stripes*) condition, the first and second primes are not directly related to each other. In this way, Balota and Paul could investigate the influence of multiple primes on target activation while avoiding the influence of direct relations between the primes.

The results of five experiments, which include both lexical decision and naming tasks (and other manipulations), yielded remarkably consistent evidence for simple additivity of priming, as shown in the data in Table 6.1. Specifically, one can predict the influence of two primes in the related–related condition by simply adding the priming effect from the related–unrelated and the unrelated–related conditions, compared with the unrelated–unrelated condition. This pattern of additivity occurred both when the target words were ambiguous (had two meanings, each of which was primed, e.g., *kidney–piano–organ*) and when the targets were unambiguous (or had one meaning, *lion–stripes–tiger*). Therefore, additivity of priming seems fairly general.

Extensions of Spreading Activation to False-Memory Paradigms

In the previous sections we have argued that activation within both episodic and semantic memory networks causes priming, spreads across multiple links, and summates. In this next section we apply the spreading activation metaphor to the

TABLE 6.1

Additivity of priming

Target	Prime type	Prime 1	Prime 2	Target	Mean	Priming effect
Unambiguous						
	RR	*Lion*	*Stripes*	*Tiger*	539	29
	UR	*Fuel*	*Stripes*	*Tiger*	551	17
	RU	*Lion*	*Shutter*	*Tiger*	555	13
	UU	*Fuel*	*Shutter*	*Tiger*	568	
Ambiguous						
	RR	*Kidney*	*Piano*	*Organ*	550	24
	UR	*Wagon*	*Piano*	*Organ*	560	14
	RU	*Kidney*	*Soda*	*Organ*	566	8
	UU	*Wagon*	*Soda*	*Organ*	574	

Note. R = related; U = unrelated. Priming effects are computed in ms with respect to the UU baseline for each target type. The predicted (UR + RU) priming effect of 26 ms equaled the observed priming effect of 27 ms in the RR condition, collapsing across the two types of items.

understanding of false recall and false recognition. We be [illegible]e chapter with the example from Underwood's (1965) research on false recognition, in which the study of one word (*table*) increased false recognition of an associated word given later (*chair*). However, false recognition effects in Underwood's paradigm are very small. Therefore, we rely on a different paradigm that produces robust false-memory effects as assessed in both recall and recognition.

The procedure is one developed by Roediger and McDermott (1995), based on earlier research by Deese (1959), and is known as the Deese–Roediger–McDermott (DRM) paradigm. In this situation, subjects hear a list of 15 words that are related to a critical nonpresented word (e.g., *bed, rest, awake, tired, dream, wake, snooze, blanket, doze, slumber, snore, nap, peace, yawn,* and *drowsy*). The words are the first 15 associates to *sleep* in the Russell and Jenkins (1954) norms. Although *sleep* is not presented, the intriguing finding from many experiments is that critical nonpresented words such as *sleep* are both falsely recalled and falsely recognized at very high levels. For example, in single trial free recall in Roediger and McDermott's (1995) experiments, the probability of recalling the critical missing word approximated (Experiment 1) or even exceeded (Experiment 2) the probability of recalling words that had occurred in the middle of the list. Similarly, the false alarm rate for these items in a recognition test after many lists have been presented equaled the hit rate of the studied items, with .81 and .79 probability of an "old" response for these two types of items, respectively. In addition, when subjects were asked to make remember–know judgments using Tulving's (1985) procedure, they reported "remembering" the nonpresented words at about the same level (.58) as words that actually were presented (.57). This pattern is in clear contrast to false alarms made for unrelated words, which occurred with low frequency (.11, showing that sheer guessing was not a problem) and were mostly judged to be known (.09) rather than remembered (.02). The DRM paradigm, therefore, produces high levels of false remembering in both recall and recognition performance.

Consider these findings within the spreading activation framework shown in Figure 6.1. The simplest interpretation is that the activation from the multiple words presented in the list converges on and primes the critical nonpresented item. If this high degree of convergence produces as much activation for the critical items that are not presented as for list items that are actually studied and if activation during study partly determines recall and recognition, then the spreading activation metaphor can be useful in understanding these phenomena. It is worth noting that McDermott (1997) showed that if the critical item is presented in the list, it is better recalled than if it is not presented (the standard DRM procedure). One interpretation of this outcome (which was replicated by Miller & Wolford, 1999) is that additional activation accrues from the study of the word relative to the standard condition (see Wixted & Stretch, 2000, for more formal specification of these ideas within a signal detection framework).

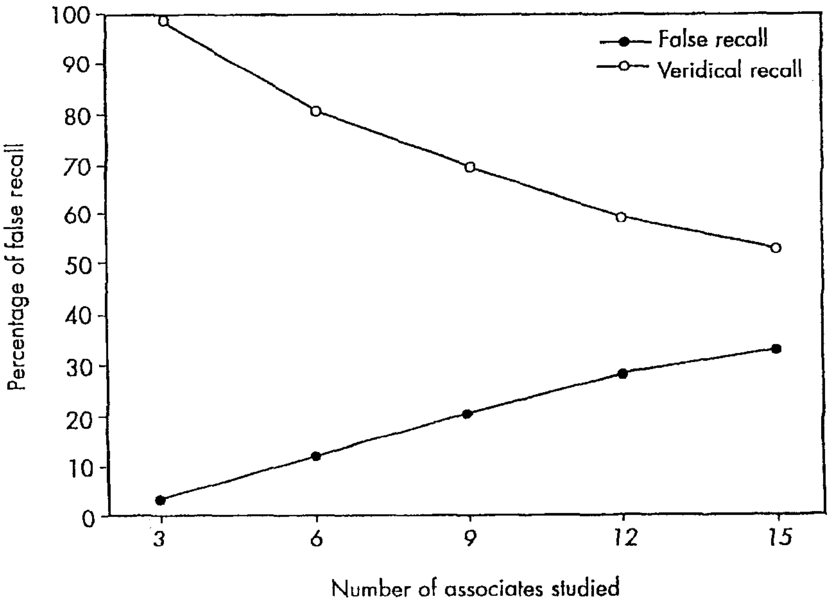
Although the [illegible]c DRM results are consistent with the activation metaphor, asking more detailed questions permits the analogy to be extended and should provide better evidence about the relevance of the framework. We now turn to these questions.

Do False Memories Summate?

The strongest prediction of an automatic spreading activation account of the DRM phenomenon is that false recall and false recognition should increase as the total amount of activation for that critical item increases. This prediction follows naturally from Balota and Paul's (1996) summation of priming studies reviewed above. In a direct test, Robinson and Roediger (1997) presented 3, 6, 9, 12, or 15 items from the DRM lists and tested memory for the lists, for both accurate and false recall and recognition. The results are shown in Figure 6.4, where it can be seen that probability of recall of list items drops with length of the list (the usual list length effect; Murdock, 1961), but recall of the critical items increases as a function of list length.

FIGURE 6.4

Mean percentage of veridical and false recall as a function of number of list items presented from the DRM lists. Data are from Robinson and Roediger (1997).



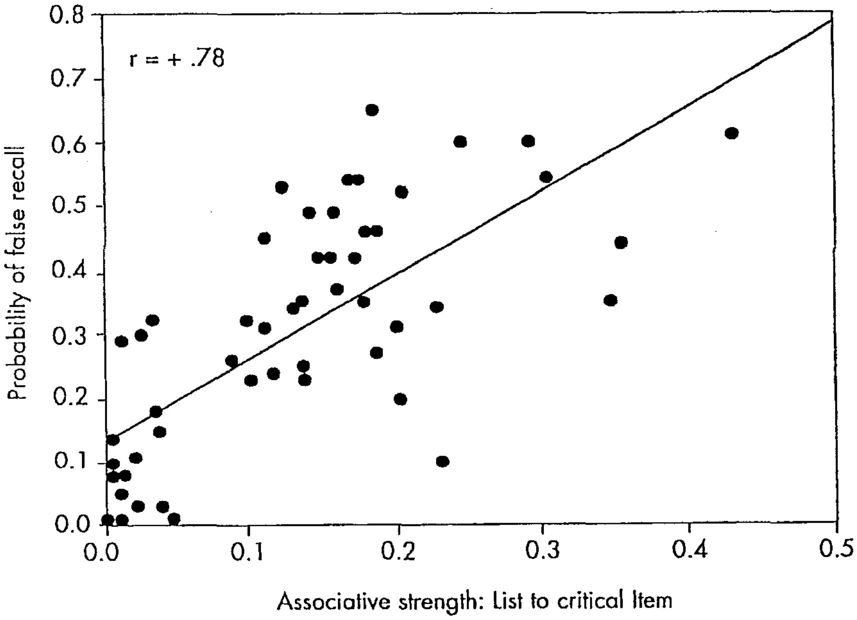
This latter finding is consistent with a spreading activation account, which predicts that activation should summate for critical items in a way that is similar to the summation of activation in semantic priming experiments. The data in Figure 6.4 came from an experiment in which only varying numbers of related words were presented, so that list length was confounded with number of related items. Robinson and Roediger (1997) conducted a second experiment in which unrelated filler words were added to the varying numbers of related words to bring all lists to 15 items, so that (for example) the list of 6 related items now included 9 unrelated fillers. It is interesting to note that adding unrelated fillers depressed the level of recall of list items but had no effect on recall of the critical items. Therefore, false recall appears to be driven by the sum of associative strength from list items to the critical item rather than the average strength because adding filler items leaves the total associative strength constant but reduces the mean strength.

Roediger, Watson, McDermott, and Gallo (in press) conducted a regression analysis that also strongly implicates the associations between list items and the critical item as determining false memories in this paradigm. They conducted a multiple regression analysis in which they entered eight factors having to do with both list characteristics and features of the critical items for 55 DRM lists. The 55 lists include 36 lists from a published study (Stadler, Roediger, & McDermott, 1999) and 19 lists developed separately (Gallo & Roediger, 2000). The range of false recall produced by these lists is .01 to .65, even though all of the lists were constructed in the same general manner by selecting the first 15 associates to a word from various word norms. The reliability of the lists in producing false recall is high, with a split-half correlation of .90.

The question of interest is what factor or factors determine the propensity of the lists to elicit false recall? Of eight factors considered, that of backward associative strength (of items in the list to the missing critical item) turned out to be the most strongly correlated with probability of false recall. That is, the degree to which the list items evoke associations to the critical item nicely predicts false recall. The correlation between backward association strength and false recall was .73, and the scatter plot is shown in Figure 6.5. Deese (1959) reported an even stronger correlation between these variables in his data, .87, but on a smaller number of lists. Backward associative strength accounted for 35% of the variance in the Roediger, Watson, et al. (in press) multiple regression analysis, far more than the only other two significant factors. This outcome strongly supports the spreading activation interpretation of the phenomenon: The more strongly associated list items are to the critical item, the more likely the critical item is to be activated, and the more likely it is to be recalled and recognized. Of course, the data in Figure 6.5 are correlational, but those in Figure 6.4 provide an experimental analysis leading to the same conclusion. The more list items tend to elicit the critical item, the greater is false recall and false recognition and, of course, associative strength also determines semantic priming effects (e.g., Balota & Duchek, 1988; Lorch, 1982). McEvoy, Nelson, and Komatsu

FIGURE 6.5

Scatter plot of backward associative strength and probability of false recall of the critical nonpresented item across 55 lists. Data are from Roediger, Watson, McDermott, and Gallo (in press).



(1999) also implicated the role of backward associative strength in producing false recall.

Is Conscious Processing of the List Items Necessary to Produce False-Memory Effects?

Evidence exists that two types of mechanisms underlie semantic priming effects. One mechanism reflects the automatic spread of activation within a memory network, as we have been discussing, whereas a second mechanism reflects a more attention-demanding process in which subjects generate conscious expectancies about the upcoming target from the prime (Neely, 1977; Posner & Snyder, 1975). One strong piece of evidence that activation can truly be automatic is that significant priming can occur for primes presented very briefly (e.g., 20 ms) and followed by a visual mask (Balota, 1983; Fowler, Wolford, Slade, & Tassinary, 1981; Marcel, 1983). These primes are clearly at or below threshold levels of identification (for a review, see Holender, 1986), and so there is very little possibility [illegible]nscious attentional mechanisms producing these priming effects.

In this context, an interesting question emerges regarding the DRM paradigm: If spreading activation is a useful metaphor to understand false memories in this paradigm, do lists presented very fast (too fast for conscious processing of the items) still elicit false recall and false recognition? In the typical DRM paradigm with relatively slow presentation rates, the critical items may become consciously activated during study of the list (McDermott, 1997). If such conscious activation of the list items were necessary to produce the phenomenon, then fast rates of presentation should eliminate the effect. However, if false memories are also aroused by automatic spreading activation, one might expect the phenomenon to persist even under fast rates of presentation. Of course, both automatic and conscious mechanisms may be at work.

To address these issues, Roediger, Balota, and Robinson (2000) presented the DRM lists at very fast durations of 20, 80, 160, or 320 ms per word, with a constant 32-ms interstimulus interval. At the fastest rate, all 15 words flashed by in less than 1 s (780 ms), with the phenomenal result that maybe one or two words were actually perceived by the subjects. After each list, subjects were required to recall as many items as possible from the list. The results show remarkable regularity between veridical and false recall. The recall of list words and the recall of critical items increased in a one-to-one fashion with progressively slower presentation rates. The probability of veridical recall was .10, .22, .28, and .31 over the four rates of presentation (from 20 to 320 ms), whereas false recall was .10, .25, .31, and .33, respectively. Assuming activation of list items increased as the rate slowed, then false recall increased in direct proportion to activation.

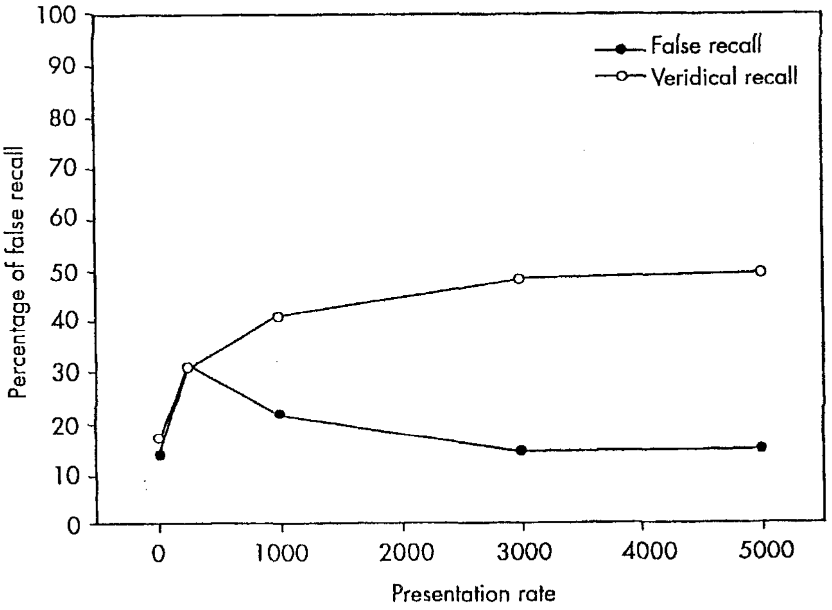
How might more strategic processes affect false recall? At some point, when strategic operations kick in, one might expect the relations between veridical and false recall to break down, with there being a discontinuity in false recall. Toglia, Neuschatz, and Goodwin (1999) and Gallo and Roediger (2000) discovered that at much slower rates of presentation, there is actually a negative association between veridical and false recall. In Gallo and Roediger's Experiment 2 with lists that produce high levels of false recall, slowing presentation across rates of .5, 1, and 3 s/item increased the probability of veridical recall from .58 to .65 to .73. However, probability of false recall decreased from .48 to .41 to .28 across these same rates. At these slower rates, when strategic processes have come into play, greater study time decreases false recall. Obviously, this pattern is inconsistent with a simple activation account of false memories—greater study time would normally lead to greater activation—and therefore suggests that other processes must be involved.

The positive correlation between study time and false recall at fast rates and the negative correlation at slow rates argue, of course, that the function relating study time to arousal of false memories is at least nonmonotonic and probably an inverted U. However, the data just discussed come from different experiments. Can both patterns be obtained in the same experiment by sampling rates from a wider range? McDermott and Watson (in press) conducted the critical experiment demonstrating that this is so and bearing out the conclusion that the function is discontinuous. Their data are shown in Figure 6.6. Level of false recall rose over fast rates and then dropped at slower rates, confirming the points made above, but within the context of a single experiment with other variables controlled.

How might one account for this nonmonotonic relation between presentation rate and veridical and false recall? With increases in presentation duration after relatively short delays, one might expect increases in both false and veridical recall as a result of spreading activation mechanisms. However at longer delays, it is possible that recollection of specific information about list items is sufficiently strong such that participants no longer rely on global activation to drive a memory response. For example, *would one expect false recall with only a three-item list?* The answer is *no* because veridical recall would be sufficiently good that the participant would rely only on item-specific information (see Robinson & Roediger, 1997). Thus, one possible way to accommodate the nonmonotonic relation between presentation rate and veridical and false memories is to consider the distinctiveness of item recall.

FIGURE 6.6

Nonmonotonic relation between presentation rate and veridical and false recall. Data are from McDermott and Watson (in press).



When item specific information is accessible, participants may be less likely to consider global activation from list items as enough to drive a recall or recognition response (for a discussion of this point, see Balota, Cortese, et al., 1999; and Kensinger & Schacter, 1999).

To return to the central issue of this section, evidence from Roediger, Balota, and Robinson (2000) leads to the conclusion that the critical item can be elicited by an automatic spread of activation among semantic associates. False recall occurred even at rates of 20 or 80 ms/item, conditions in which conscious activation of the lure during study is unlikely. (Indeed, conscious activation of most list items is questionable at these rates.) Seamon, Luo, and Gallo (1998) reached similar conclusions about the automaticity of false memories when they obtained robust recognition of critical items under conditions that minimized conscious awareness of the study words. These conditions included both rapid presentation rates and division of attention during study. This outcome establishes another similarity between research on semantic priming and false memory and extends the spreading activation metaphor, at least at relatively fast presentation rates, to the domain of false memories.

Individual Differences in the DRM Paradigm

If false memories within the DRM paradigm are created by an automatic spread of activation among semantic associates, then interesting predictions can come from research on populations besides healthy young subjects. In particular, research with older adults and individuals with dementia of the Alzheimer's type (DAT) shows a pattern of intact automatic activation of information but impaired attentional processes. For example, both groups demonstrate robust semantic priming effects (Balota & Duchek, 1991; Balota, Watson, Duchek, & Ferraro, 1999; Ober & Shenaut, 1995). The automatic spreading activation component of priming is also intact in these populations, but the more attentional mechanism appears to break down (Balota, Black, & Cheney, 1992; Ober & Shenaut, 1995). If the creation of false memories reflects the automatic spread of activation among semantic associates, then one might predict that healthy older adults and individuals with DAT would be likely to produce false memories. Indeed, if the breakdown in attentional control and monitoring processes fails to inhibit false memories, as may occur in younger adults, then the tendency to false recall and false recognition may even be exaggerated in these populations. In fact, several researchers have shown exactly this pattern: Relative to young adults, older adults and DAT patients show worse recall of list items in the DRM paradigm, but relatively greater false recall (Balota, Cortese, et al., 1999; Norman & Schacter, 1997; Tun, Wingfield, Rosen, & Blanchard, 1998). Therefore, comparisons among groups provide converging evidence regarding the role of spreading activation in producing false memories.

Hybrid-Cue False-Memory Paradigms: Limits to the Spreading Activation Analogy

In the remaining portion of this chapter, we consider one situation in which the parallel between spreading activation in a short-term priming paradigm and in the DRM false-memory paradigm does not hold. Watson, Balota, and Paul (2000) used naming and lexical decision tasks to address whether priming would summate with primes that tapped semantic and orthographic–phonological dimensions using the multiprime paradigm shown in Figure 6.1. In the related condition, subjects received semantic (*rest*), orthographic–phonological (*weep*) primes, or both that converged on a target (*sleep*). Priming occurred from both types of prime independently (10 ms from semantic primes, 15 ms from orthographic–phonological primes), and the combination of primes across the semantic and orthographic–phonological codes nearly added together (a 22-ms priming effect). This additive pattern is consistent with the original Balota and Paul (1996) studies with semantic primes.

Watson, Balota, and Roediger (2000; see also Watson, Balota, & Sergent-Marshall, in press) extended this mixed code procedure to the DRM paradigm by developing lists that had either semantic associates, orthographic–phonological associates, or both types of items (hybrid lists) that converged on a critical nonpresented item. For example, in the hybrid list condition, with the critical item *sleep*, the list items were *bed, steep, rest, weep, tired, sleet, awake, bleep, dream, slope, snore,* and *seep,* among others. It is interesting to note that Watson, Balota, and Roediger obtained a different pattern of results in the DRM paradigm relative to the data from speeded naming experiments regarding mixed codes, reviewed above. The hybrid lists produced a much higher probability of false recall (.64) than predicted from an additive combination of independent estimates of semantic (.33) and orthographic–phonological (.17) probabilities of false recall. Although this outcome appears to limit the application of the spreading activation metaphor to account for the creation of false memories, we believe the activation account is still viable—both types of primes activate the critical item—but that an extra factor creates the superadditivity.

What might produce the superadditive recall of critical items in the hybrid-cue condition? Although future research will be needed to fully address this issue, we suspect that this outcome results from an interplay between semantic and orthographic–phonological networks which, although absent in priming measures, is present in the episodic retrieval environment and influences recall. Rubin and Wallace (1989) provided direct evidence for such a mechanism in a word generation task. Subjects who were given meaningful cues such as "a mythical being" did not produce *ghost;* similarly, those who were given the cue "rhymes with *ost*" failed to produce *ghost.* However, if given the cue "a mythical being that rhymes with *ost*," they produced *ghost* every time. The independent cues were ineffective in evoking the response, but the compound cue always did. The reason is that the two cues converge on a single concept, whereas the independent cues could e [illegible] any concepts. This pattern of specificity in recall is also consistent with Watkins's (1975) arguments about cue overload, that is, having a more distinctive cue environment greatly augments recall—but in this case false recall. (See chapter 15 by J. S. Nairne for the importance of distinctiveness in retrieval processes.) In our pure lists, the critical concept could be activated either by the semantic or the orthographic–phonological items, but many items were activated. However, in the hybrid lists, the critical item was uniquely specified by the activation of two intersecting dimensions; so conditions at retrieval were most effective in eliciting recall of the critical item, even though it was not presented.

Clearly, additional research will be necessary to determine the exact cause of the false recall–priming paradox that is observed with hybrid cues, but we think the intersecting activation from two sources that more distinctively specifies the target may hold the key. Whatever the cause of the superadditivity, the hybrid list condition produces the largest false-recall effects ever observed in the literature. Subjects falsely recalled the critical concept on 64% of the trials.

Another study is directly relevant here. Sommers and Lewis (1999) also obtained high levels of false recall and false recognition by presenting subjects with lists of items that all come from the same "neighborhood" of words, in terms of Luce and Pisoni's (1998) neighborhood activation model of speech perception. If a subject studies words such as *hat, bat, cot,* and *cab*, all from the same word neighborhood as *cat,* false recall of *cat* is high. The model assumes that spoken words activate neighbors during perception. Therefore, when many neighbors converge on the same word, it is activated many times, which leads to false recall and false recognition. Sommers and Lewis's (1999) work further supports the idea that activation processes are critically important in the creation of false memories.

Conclusion and Caveats

The focus of this chapter has been on the relevance of spreading activation, as typically measured by priming paradigms, for the creation of false memories. We believe the evidence is persuasive in validating our analogy between activation in short-term priming phenomena and in the DRM false-memory paradigm. We reviewed several lines of evidence that support this framework. However, we do not want to leave the impression that activation during encoding is the *only* factor at work in the DRM paradigm. Clearly, the same spreading activation that has been reviewed in this chapter is likely to occur both at encoding and during retrieval. Indeed, Roediger and McDermott (1995, 2000; also see Roediger, McDermott, & Robinson, 1998) have discussed a multiplicity of processes during both encoding and retrieval that may operate in this situation, and many other perspectives (e.g., the fuzzy trace theory by Reyna & Brainerd, 1995) have been useful in aiding the understanding of these phenomena. I chapter, we emphasize encoding processes and, relatively speaking, neglected retrieval processes. However, we firmly believe that a more complete account of these interesting and puzzling phenomena must include factors operating at encoding, at retrieval, and in their interaction (Roediger, 1999). We tell only part of the story in this chapter, but our intent is to show that activation plays a critical role in priming and in the creation of false memories.

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