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The Rise and Fall of False Recall: The Impact of Presentation Duration

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The effect of presentation duration on false recall induced by presentation of semantically associated and phonologically associated word lists was examined. When 16-word lists comprised of semantically related words (e.g., *bed, yawn*) were presented at short durations (i.e., 20 or 250 ms/word), false recall of related but nonpresented words (e.g., *sleep*) increased with increasing duration. However, at longer presentation durations (i.e., 1000, 3000, or 5000 ms/word), false recall declined with increasing presentation duration. This pattern resolves discrepancies among previous experiments investigating the effects of presentation duration on associatively induced false recall. Further, these data constrain theoretical accounts of false recall in that single-process models cannot readily account for these effects. We propose a dual-process model that appears to account for these findings and much of the extant literature. Phonologically related lists (e.g., *sweep, sleet*) exhibited a very different pattern of results at the short presentation durations; specifically, false recall was exceedingly high at the fastest duration and declined as duration lengthened. Similarities and differences between the mechanisms underlying semantically and phonologically induced false recall are considered.

Key Words: false recall; presentation duration; associatively-induced false recall.

Interest in false memory has recently led to the introduction of new laboratory techniques with which to study the phenomenon, which in turn has led to significant advances in our understanding of the processes giving rise to false memories. One of these new techniques, introduced by Roediger and McDermott (1995), is a modification of a procedure introduced decades earlier by Deese (1959) for other purposes. This technique offers a straightforward means of reliably inducing false recall and false recognition. The procedure is as follows: Participants are given a short list of words to remember; typically, 15 words are presented auditorily at a relatively slow rate (e.g., a word every 1.5 s). Immediately after list presentation, subjects are asked to recall in any order (without guessing) as many of the words as they can remember. Subjects reliably introduce a single, highly predictable word into their recall. This word is strongly associated to all the presented words but is not itself presented. For example, list words might include *door*, *glass*, *pane*, *shade*, *ledge*, *sill*, *house*, *open*, *curtain*, *frame*, *view*, *breeze*, *sash*, *screen*, and *shutter*. When presented with such a list and asked immediately afterward to recall the list words, subjects often (approximately half the time, with the procedures described above) report remembering having heard *window*.

The experiment reported here was motivated by a desire to better understand the mechanism(s) underlying false recall. A number of theoretical accounts have been forwarded to explain this phenomenon, and several of these are reviewed under Discussion. Briefly, although some researchers have argued for the importance of encoding processes, others have emphasized retrieval processes or even advocated that the source of the phenomenon is nothing more than a criterion shift adopted during retrieval (Miller & Wolford, 1999). One purpose of this experiment was to demonstrate empirically that more than one process underlies false recall with this procedure. That is, if parametric manipulation of a variable (e.g., presentation duration of list items) produces a U-shaped relation with the probability of false recall, more

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than one process can reasonably be argued to determine the likelihood with which these procedures elicit false recall.

Why did we think manipulating presentation duration would produce a U-shaped pattern? An examination across experiments (many as yet unpublished) suggested this outcome. At fast presentation durations, most relevant is an experiment by Roediger, Robinson, and Balota (2001), who showed at very rapid durations a remarkable positive correlation between accurate and false recall. They manipulated presentation duration at 20, 80, 160, and 320 ms and showed monotonic increases in false recall with increasing presentation duration; further, these increases paralleled closely the increases seen in accurate recall. That is, false recall probabilities increased with increasing duration (.10, .25, .31, and .33), as did accurate recall probabilities (.10, .22, .28, and .31).

With respect to manipulation of slower presentation durations and the effect on immediate free recall, the pattern of results emerging seems to suggest the opposite pattern: With lengthier presentation durations, false recall is attenuated. For example, Toglia and Neuschatz (1996) reported decreases in false recall on tests given immediately after list presentation when interstimulus intervals (ISIs) were lengthened from 1s (.72 false recall) to 4 s (.49 false recall). Gallo (2001) has obtained similar data, with false recall dropping with slower presentation rates; false recall declined from .47 to .40 to .26 in one condition with ISIs of 500, 1000, and 3000 ms, respectively.

Results on final recognition tests, although less directly relevant to the immediate free recall conditions explored in the present experiment, generally suggest similar patterns of results at the short presentation durations, although baserate differences across conditions can complicate interpretation of these results. Seamon, Luo, and Gallo (1998) showed that across presentation durations of 20, 250, and 2000 ms, false recognition of the critical nonpresented items on a test given after study of multiple lists tended to increase with increasing duration when corrected for baserate differences (from .41 to .43 to .49 in one condition and .18 to .32 to .34 in another condition). Arndt and Hirshman (1998) showed systematic increases in false recognition across durations between 300 and 3000 ms in four relevant conditions; one of the four (Experiment 1) also showed a small hint of a decline at the longest presentation duration (3000 ms), but this decrease was accompanied by baserate differences, leading Arndt and Hirshman to conclude that false recognition leveled off (but did not decline).

In summary, although some studies have shown increases in false recall and false recognition with increasing presentation duration and others have shown the opposite, cross-experiment comparisons led us to believe that the presentation parameters differed enough across studies that the results might be reconciled by a single study in which presentation duration was manipulated across a wide range of durations. We chose free recall as a dependent measure to avoid baserate problems inherent in recognition, and we note that caution should be warranted in generalizing our results to false recognition, especially when given after presentation of multiple lists.

To this end, we presented subjects with semantically related lists; words within the lists were presented for varying durations. The primary question was whether false recall would show an inverted U-shaped relation with presentation duration such that false recall would increase with increasing presentation durations at the fast durations and then decline at the slower durations. Such a pattern, if obtained, would constrain theoretical interpretation of the associatively-induced false recall phenomenon and strongly implicate a two (or more) factor theory.

In addition, a separate set of subjects received lists comprised of phonological associates (e.g., *deep*, *weep*), which converged on a phonologically similar nonpresented word (e.g., *sleep*). Prior work by Watson, Balota, and Roediger (2001) and by Sommers and Lewis (1999) had demonstrated that robust false recall could be attained through the presentation of phonologically related words; in addition, false recognition of phonologically related words has also been reported (Cramer & Eagle, 1972; Schacter, Koutstaal, Johnson, Gross, & Angell, 1997;

Schacter, Verfaellie, & Anes, 1997; Wallace, 1968; Wallace, Stuart, & Malone, 1995; Wallace, Stewart, Sherman, & Mellor, 1995). Although we made specific predictions with respect to the effect of presentation duration on semantically induced false recall, use of the phonological lists was exploratory and was performed in an attempt to gain leverage on the question of whether similar or different mechanisms might underlie false recall elicited by the two types of lists. We performed one large between-subjects experiment with five levels of presentation duration and two types of lists.

METHOD

Subjects

Subjects were 350 recruits in their 6th week of basic training at Lackland Air Force Base. They were tested in large groups at the Test Development Center, operated by staff from the Learning Abilities Measurement Program (LAMP).

Discarding subjects who did not follow directions left at least 31 subjects in each condition; to equate power in all conditions, we discarded some additional subjects (chosen at random) and analyzed data from 31 subjects in each of the 10 conditions.

Design and Materials

Presentation duration was varied between subjects, with five levels of this factor (20, 250, 1000, 3000, and 5000 ms). List type (semantic and phonological) was also varied between subjects. Thirty-one subjects contributed to each of the 10 between-subjects conditions of the 5×2 design. Because each subject received all 36 lists (either semantic or phonological) at a single presentation duration, no counterbalancing was required.

Seventy-two lists were constructed around 36 critical nonpresented items. For the 36 semantically related lists, list construction was modeled loosely after the procedure used by Roediger and McDermott (1995), whereby the top associates to critical nonpresented words were collected. To facilitate comparisons in the false recall patterns induced by these semantically associated lists and those induced by phonologically associated lists, we held the critical nonpresented words constant across list structure. Doing so imposed restrictions on the critical nonpresented words we used, so we were unable to simply adopt Roediger and McDermott's set. For example, the critical nonpresented word *mountain* does not have enough phonological neighbors to participate in the phonological condition and therefore was not used in either condition. Phonologically related lists were constructed by obtaining words that differed from the critical nonpresented item by substituting, adding, or deleting a single phoneme (or, on occasion, more than one phoneme). The entire set of 72 16-word lists appears in the Appendix of Watson, Balota, and Roediger (2001) and is available from the present authors upon request.

Each subject studied 36 lists, presented visually at a single presentation duration. For each subject, the order of lists was randomly determined, but order of words within lists was constant. Note that although Roediger and McDermott (1995) and most other researchers have presented items in the order of strongest to weakest associates, we had no measure of associative strength for the phonological lists; therefore, we presented words in a single random order for both semantically and phonologically associated lists. Words in the odd-numbered serial positions were presented in uppercase letters, and those in even numbered positions were presented in lowercase; this manipulation was implemented in an effort to minimize misperception at the fastest presentation durations for the phonological lists (e.g., *sleet* and *sweep* misperceived as *sleep*).

Procedure

Subjects were seated at computer terminals with dividers separating the terminals. All instructions were presented via computer. Each subject received a test packet, in which they were to recall the lists. The instructions appeared on the face page of the test packet. Instructions for the "fast" presentation rates (i.e., 20 and 250 ms) and the "slow" rates differed very slightly as necessary to prepare subjects for the task; these differences are presented below in brackets. The entire set of instructions was as follows:

> This is a test of your memory abilities. You will be shown words on the computer screen. The words will be presented one-at-a-time. Your job is to try to remember as many of the words as possible. The words will be presented in lists (with 16 words in each list). Please pay very close attention to the words as they go by on the screen because [*FAST*: the words will be presented VERY QUICKLY; *SLOW*: your memory will be tested].
>
> You will be shown a total of 36 lists (16 words in each list). After each list of 16 words, you will take a memory test. You will have 45 seconds to write down all the words that you can remember FROM THE LIST THAT WAS JUST SHOWN. The memory test for each list should be done on a separate page in your booklet. It is important that you DO NOT GUESS when you are trying to remember the words from the list. Only write down those words that you are sure you saw. If it ever happens that you cannot remember ANY of the words, just write an “X” on that page. We realize that this is a difficult task, so please do not get discouraged. We simply want you to try as hard as you can.
>
> Before you begin, there will be one practice list. The practice list is similar to the other 36 lists in that it will be presented at the same speed. When you are ready to see the list, you will press the ENTER key. The computer will then make a warning sound to signal that the words are about to appear. The computer will then present 16 words one-at-a-time. The computer screen will then tell you to start recalling. DO NOT begin writing until the computer screen instructs you to do so. The computer will also make a tone when it is time for you to stop recalling.
>
> You will notice that some words are printed in uppercase letters, and some words are printed in lowercase letters. This is NOT important! We just want you to try to remember as many words as you can (but without guessing).
>
> If you understand these instructions, you may press <ENTER> to see the practice list. If you do not understand the instructions, please re-read them, and then ask the proctor (if you are still unsure about the procedure).

Although words were presented for varying durations, the interstimulus interval (ISI) was held constant (at 32 ms) across all conditions. Due to monitor refresh rates, the exact timing of the stimuli were multiples of 16.6 ms, and therefore although we specified 20 ms as the lowest duration, the actual presentation duration for this condition approximated 32 ms; our levels varied widely enough that small fluctuations in the exact timing would not result in any overlap among conditions. Presentation of each list lasted just over 1 s in the 20-ms condition and about 1 min and 20 s in the 5000-ms condition. Subjects initiated the beginning of list presentation by pressing a key. Words were presented in the center of the screen. Following the last list item, a message appeared on the screen, which told subjects to write down the words they remembered in any order but to avoid guessing; 45 s were allowed for the recall period, and a countdown timer was displayed on the screen. Once the 45 s had expired, the computer emitted a 1-s tone, and subjects then pressed a key to see the subsequent list. Upon completion of all 36 study-test trials subjects were thanked and debriefed.

RESULTS

Recall Probabilities

The probabilities of recall of the studied items and critical nonpresented items as a function of presentation duration and list type are depicted graphically in Fig. 1. The left panel displays data for the semantic lists, and the right panel displays data for the phonological lists. Turning first to the primary question of interest, we can see that indeed false recall of the critical nonpresented words in the semantic lists (left panel, open circles) exhibited an inverted

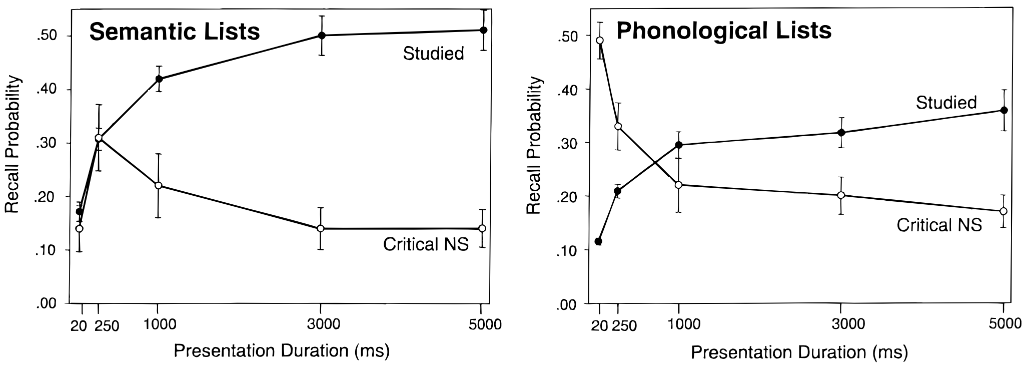

FIG. 1. Probability of recall of studied items and critical nonstudied items as a function of presentation duration for semantically associated lists (left panel) and phonologically associated lists (right panel). Error bars represent the 95% confidence interval. NS = nonstudied.

U-shaped relation with presentation duration. That is, false recall initially increased with increasing duration, peaked, and then fell with further increases in presentation duration. Thus, our principal hypothesis was confirmed: False recall of semantically related lists varied in a U-shaped relation with presentation duration.

In addition, an examination of both panels of the figure suggests that the two list types manifested globally similar patterns of results, with one striking exception. That is, recall of studied items demonstrated steady increases with presentation duration for both list types, although the semantically associated lists led to superior recall. With respect to false recall, at presentation durations of 250 ms and greater, semantic and phonological lists behaved very similarly. However, extreme differences were observed at the fastest presentation duration: Semantic lists showed a rise in false recall from 20 to 250 ms (.14 to .31), whereas phonological lists exhibited a decline over the same intervals (.49 to .33). These general observations were suggestive of a three-way interaction, which was indeed significant, $F(4, 300) = 10.32$, $MS_e =$ .102. (All results reported as significant met the $p < .05$ criterion.) We therefore examined the semantic lists and phonological list items in separate 5 (presentation duration) × 2 (item type) ANOVAs.

Semantic lists. The semantically associated lists exhibited a main effect of item type, $F(1, 150) = 251.57$, $MS_e = 2.81$, which indicates that studied items were recalled with a higher probability than critical nonpresented items. There was also a main effect of presentation duration, $F(4, 150) = 21.03$, $MS_e = .331$, which was largely attributable to the low levels of recall (both accurate and false) in the 20-ms condition. The interaction of presentation duration and item type was reliable, $F(4, 150) = 41.77$, $MS_e = .47$. Although accurate and false recall were highly similar at the two fastest durations, the curves diverged after 250 ms, with accurate recall continuing to rise across durations and false recall taking a downturn. That is, the probability of accurate recall increased from .17 to .31 to .42 to .50 to .51 with increasing duration, and the probability of false recall varied from .14 to .31 to .22 to .14 to .14 with increasing duration.

Phonological lists. The phonologically associated lists exhibited a main effect of item type, $F(1, 150) = 4.38$, $MS_e = .04$, indicating that the critical nonpresented items were recalled with a greater overall probability than the studied items. The main effect of presentation duration was marginally significant, $F(4, 150) = 2.17$, $MS_e = .019$, $p = .076$. The effect of most interest was, as in the case for the semantic lists, the interaction between item type and presentation duration. This interaction was significant, $F(4, 150) = 91.00$, $MS_e = .79$. The crossover interaction demonstrates that as presentation duration increased, the probability of accurate recall also increased and the probability of false recall decreased. Specifically, the probability of accurate recall increased from .12 to .21 to .29 to .32 to .36 across the five presentation durations; the probability of recall of critical nonpresented items fell from .49 to .33 to .22 to .20 to .17 with increasing durations. Note that at the shortest (20 ms) presentation duration, at which point accurate recall in the phonological condition was only .12, false recall was an impressive .49. That is, the probability of false recall exceeded the probability of accurate recall by a factor of 4. We consider possible reasons for this remarkable discrepancy under Discussion.

Serial Position Analyses

Because the primary reason for including the phonological lists was to gain leverage on whether the general mechanisms underlying phonological false recall are similar to the mechanisms underlying semantic false recall we also analyzed the serial position curves for the two types of lists. These curves are shown in Fig. 2; the data shown here are raw (unsmoothed) data, which are highly stable, with 1116 observations per datapoint. The solid lines represent accurate recall as a function of serial position, and the dashed lines represent probability of false recall (where position is not relevant because these items were not studied). In general, although the semantic lists were better recalled than the phonological lists, the curves appear qualitatively similar: Both showed primacy and recency effects (for accurate recall), especially at the fastest presentation durations; further, with the exception of the 20-ms condition the probability of false recall was generally similar for the two types of list, although the relative probability of false compared to accurate recall differed across list type and presentation durations. In general, false recall probabilities hovered around recall probabilities for items presented in the middle of the lists (as observed by Roediger & McDermott, 1995; Payne, Elie, Blackwell, & Neuschatz, 1996). However, presentation duration clearly exerted an influence on this relation.

Output Position Analyses

Further analyses to try to identify differences as a function of list structure included an examination of the output position of the nonpresented item in conditions in which it was mistakenly recalled. We examined all cases in which the critical item was inaccurately recalled and plotted the cumulative probability of recall for the item as a function of quintile of that subject's output for that list (see Roediger & McDermott, 1995, for a similar analysis). That is, we examined only critical items that were recalled and created a ratio for each item (of its output position relative to the total number of words recalled for that list). We then tallied the proportion of those ratios that fell between .00 and .20 (inclusively, the first quintile of output), between .20 and .40 (the second quintile of output), and so on. These cumulative recall probabilities are presented in Fig. 3. For example, the data shown at the third quintile represent the proportion of items that were recalled in the first, second, or third quintile (with the difference between the probabilities at the second and third quintiles representing the proportion of items recalled within the third quintile of output).

The general conclusions we draw from these curves are the following. First, although there is no obvious placement of the critical nonpresented item at any certain spot in the output sequence, there nevertheless is some systematicity to output position. The straight lines shown in each graph represent the line that would be obtained if there were absolutely no systematicity to subjects' placement of the critical item. The finding that, in general, the obtained output curves fall below that line indicates that subjects tended to recall the critical items toward the end of their output sequence more than toward the beginning. (If the critical items had tended to occur toward the beginning, the output curves would have fallen above the straight line.) The 5000-ms condition is the only one suggestive of nonsystematicity, as placement of both phonologically and semantically induced false recall was distributed evenly across all output conditions.

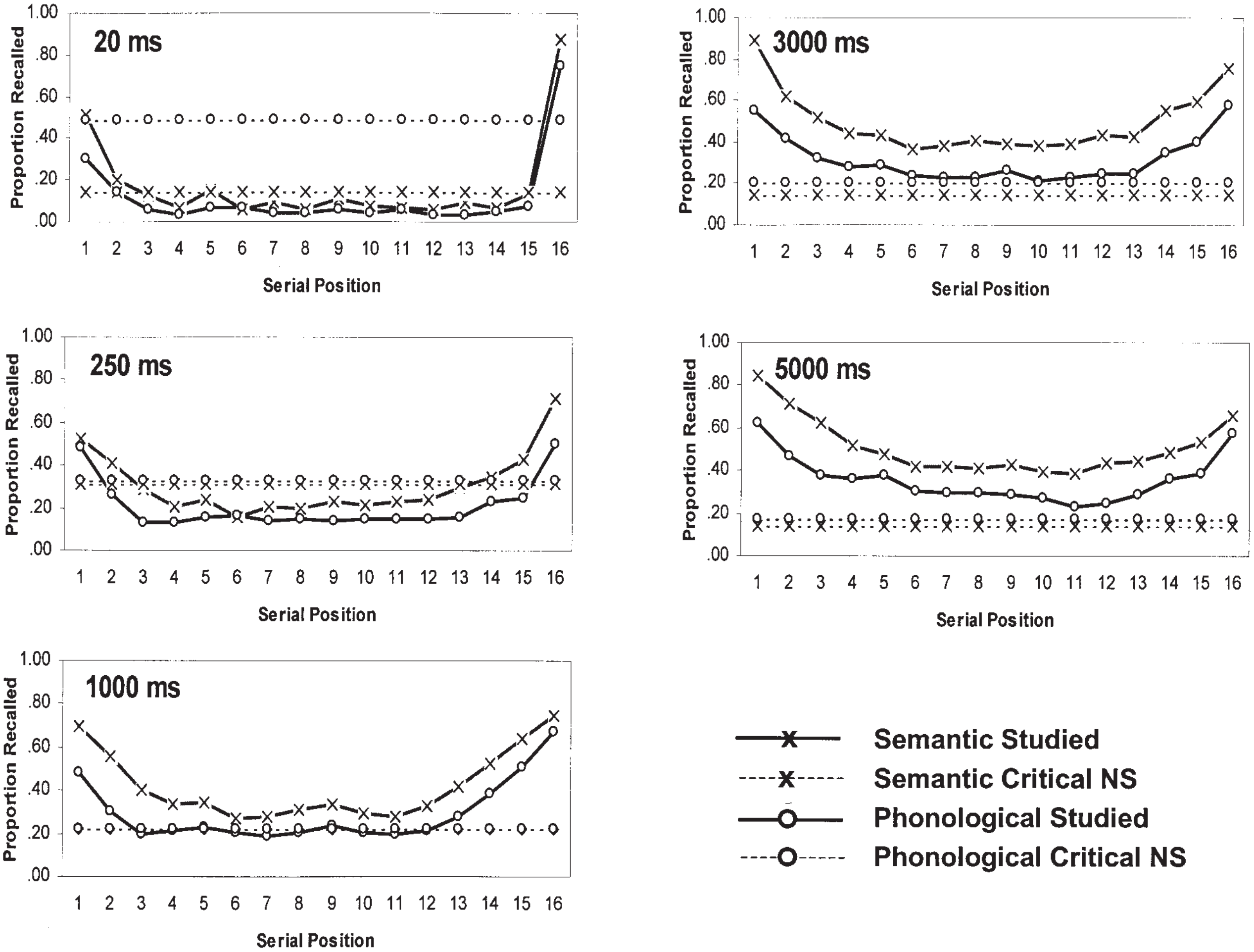

FIG. 2. Serial position curves for semantically related and phonologically related lists as a function of presentation duration. Dashed lines represent recall of the critical nonstudied words. NS = nonstudied.

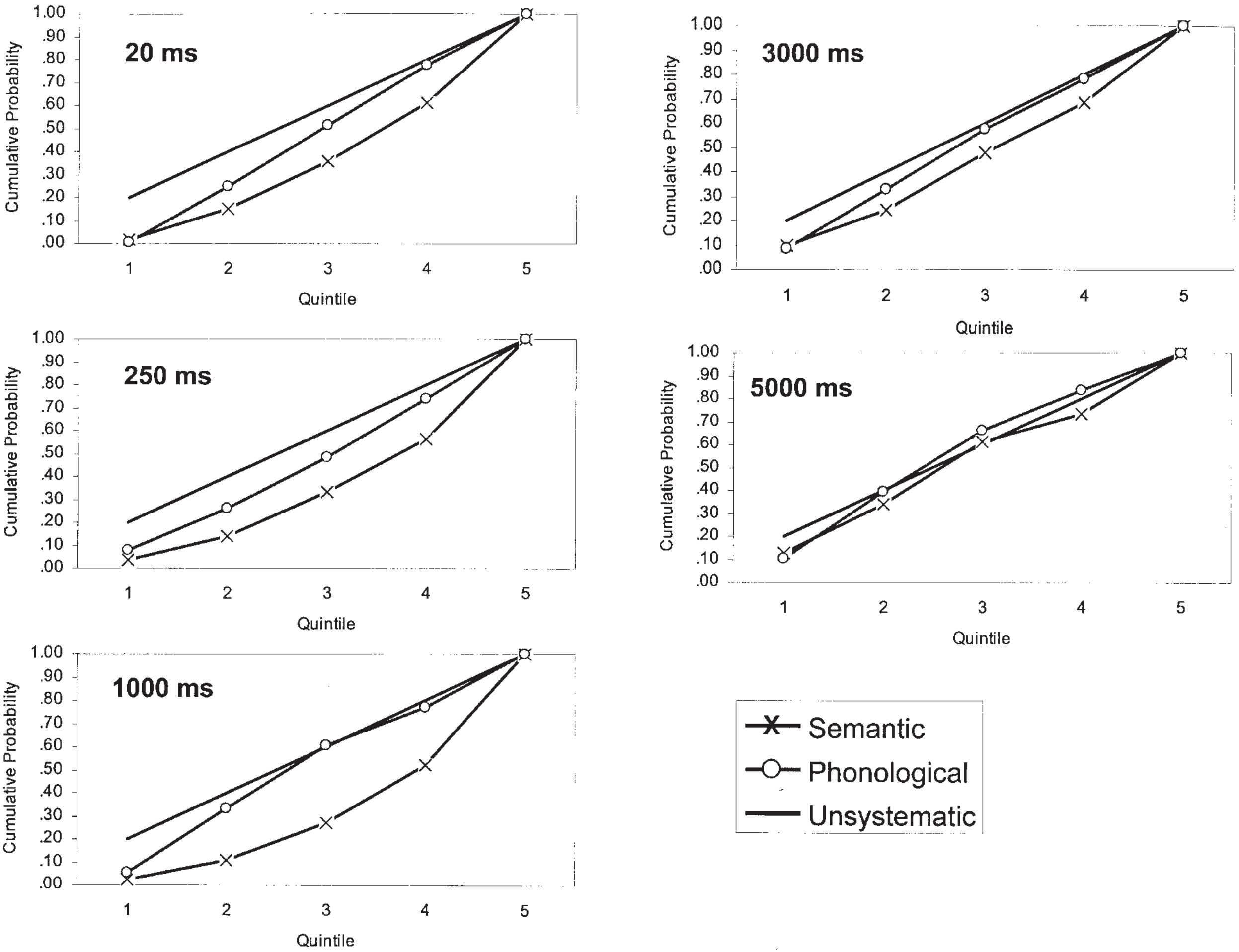

FIG. 3. Output position curves for semantically related and phonologically related lists as a function of presentation duration. These figures show where in the output sequence the critical nonstudied word tended to fall when it was indeed recalled. The straight line (labeled "unsystematic") represents hypothetical data exhibiting no systematicity to the output position.

The 1000-ms condition represents the condition in which phonological and semantic outputs differ most with respect to output position. Interestingly, this condition is the one most similar procedurally to that reported by Roediger and McDermott (1995), in which similar results were found with respect to the semantic condition in that subjects tended to produce the critical items toward the end of their output sequence. The 20-, 250-, and 3000-ms conditions show a similar, but less pronounced, pattern.

Taken as a whole, the output position curves suggest that phonological intrusions may appear in less systematic output positions than semantic intrusions, although the differences are not dramatic.

DISCUSSION

The experiment reported here provides several new findings. Our principal finding is that for semantically associated lists, the probability of false recall varied in a U-shaped fashion across presentation duration. That is, at short durations, increasing the duration of presentation led to increases in false recall probabilities. At longer durations (i.e., greater than 1 s), the opposite pattern emerged: Increasing the duration of presentation resulted in decreases in false recall probabilities. This finding is important in part because it helps resolve a seeming discrepancy in the emerging literature. More importantly, it suggests boundaries for theoretical interpretation of this false recall phenomenon: Single-process approaches cannot readily account for these data. We return to this latter point below.

Our second main finding is that the phonologically related lists exhibited both similarities and differences in false recall relative to the semantic lists. That is, false recall was extraordinarily robust with the rapid presentation durations (.49 at the 20-ms duration compared with only .12 accurate recall and .14 false recall for the semantic lists at this duration). Further, phonologically induced false recall showed declines across all presentation durations. However, if one puts aside the 20-ms condition, the semantic and phonological lists behaved similarly with respect to recall probabilities as a function of presentation duration. We suggest one interpretation of the 20-ms phonological data below.

Third, examination of serial position functions and output position functions provided subtle hints of possible differences between the two types of lists, but no marked differences were manifested.

We consider below the implications of these results for our understanding of false recall. We discuss first our view of the mechanisms underlying false recall as induced by the semantic lists and how our results fit into this framework. We then consider what our phonological results might mean and whether the mechanisms underlying the two types of effects can reasonably be argued to differ.

Mechanisms Underlying False Recall

Semantically Associated Lists

Considerable attention has been devoted toward uncovering the mechanism(s) underlying false recall as induced by lists of semantic associates. We have proposed that two processes seem to influence the probability with which these lists will induce false memories: activation and monitoring (Roediger & McDermott, 2000; Roediger, Watson, McDermott, & Gallo, in press; see Balota et al., 1999, for a similar framework). Below we describe the two processes, evidence for their importance, and how the present data fit into this framework.

Activation. False recall and false recognition may result (at least in part) from spreading activation (Collins & Loftus, 1975), whereby concepts related in semantic memory are thought to be linked in such a way that accessing one concept (e.g., *door*) sends activation across these linked pathways to related concepts (e.g., *window*). The spread of activation through the associative network primes related concepts, making them more easily accessible subsequently. This activation process is thought to occur automatically and therefore to be fast-acting, obligatory, and not amenable to conscious control (Posner & Snyder, 1975). By this account, the critical nonpresented word is highly primed to the point of being later recalled (see Roediger, Balota, & Watson, 2001).

We now consider the evidence suggesting the importance of activation processes (see also Roediger, Balota, & Watson, 2001). Although semantic activation cannot be measured directly, the stronger the associative links between list words and the critical words, the greater the level of activation. Deese (1959) reported a strong positive correlation between the probability of false recall and the degree of association between list words and the critical words. Roediger, Watson et al. (in press) replicated and extended this correlation; in a large multiple-regression analysis (with 7 factors), the associative strength of list words to the nonpresented word was the strongest predictor of false recall.

Seamon et al. (1998) reported that false recognition persisted at very fast presentation durations (20 ms); these researchers noted that at this fast rate, there was insufficient time for subjects to elaborate upon the presented items because they simply went by too quickly. Therefore, Seamon et al. argued that automatic activation was responsible for the observed false recognition effect. Robinson and Roediger (1997) manipulated list length and found that as the number of semantic associates within a list increased, so did the probability of false recall. Activation is relevant because, they argued, the number of presented associates of a critical nonpresented word should correlate positively with the activation level of that word (Balota & Paul, 1996).

Balota et al. (1999) took a different approach; instead of manipulating independent variables to modulate the activation level of the critical nonpresented word, Balota et al. examined subjects from five populations who were thought to be equated in their activation processes but to differ in other, more strategic processes (e.g., attentional control, or monitoring, as is discussed below). Specifically, young adults, young-old adults, old-old adults, patients with very mild disease of the Alzheimers type (DAT), and patients with mild DAT were tested. To the extent that activation processes contribute to false recall, one might expect these groups to exhibit similar levels of false recall, even though accurate recall worsens incrementally from the young to young-old, old-old, very mild DAT, and mild DAT. Indeed, this pattern was found; old adults and DAT patients exhibited "intact" false recall. (Actually, the probability of false recall for the young adults was slightly lower than that for the other groups, which is discussed with respect to monitoring below.) The important point with respect to activation is that groups with similar activation processes (but breakdowns in other memory-related processes) produce similar levels of false recall (see Watson, Balota, & Sergent-Marshall, in press, for a replication and extension).

The present results (for the semantic lists) are consistent with this viewpoint; to a point, as presentation duration increases, so does false recall. We believe that this increase is due to a buildup in semantic activation that occurs with increasing presentation duration (from 20 to 250 ms). Complementing the present dataset is a finding by Roediger, Robinson, and Balota (2001), who manipulated presentation duration at four very short intervals (i.e., 20, 80, 160, and 320 ms) and showed increases in false recall with increasing presentation duration; further, these increases paralleled closely the increases seen in accurate recall. Therefore, semantic activation can contribute to false recall; as activation levels accumulate across increasing presentation durations, so does false recall (at least at the relatively fast rates). Further, our data and those of Roediger, Robinson, and Balota (2001) are quite consistent, as can be seen in Fig. 4. Roediger et al.'s data augment ours by filling out intermediate points along the line drawn between our 20- and 250-ms durations. Thus, the increase between 20 and 250 ms can be considered to be roughly linear, although not strictly so.

One might argue that our (and Roediger, Robinson, & Balota's, 2001) data are simply another instantiation of the list length effect reported by Robinson and Roediger (1997). This obviously would not be a complete explanation for our results because it (like any single process explanation) cannot easily accommodate the U-shaped function obtained here. Nevertheless, one might attempt to explain two of our datapoints in this way. That is, in the fastest presentation durations, our subjects recalled

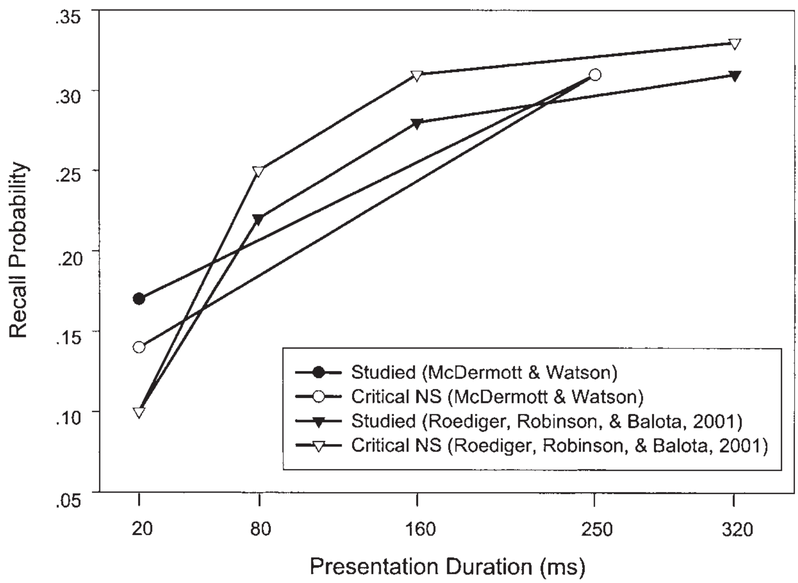

FIG. 4. Probability of recall of studied words and critical nonstudied words as a function of presentation duration for Experiment 1 of the present article in comparison to Roediger, Robinson, & Balota's (2001) Experiment 1. NS = nonstudied.

only a couple of list items (on average). As can be seen in the serial position analyses, these words were typically at the beginning and end of the list. What if people only encoded these 2–3 words, and therefore the reason recall increases from 20 to 250 ms is that more list words were encoded? That is, accurate recall rises across this interval from a probability of .17 to .31, or from approximately 2.7 words to 5.0 words per list, and one could argue that this increase represents essentially an increase in list length, which is known to influence the probability of false recall (Robinson & Roediger, 1997). There are several responses to this potential objection. First, the list length effect is not a mechanism. It is our belief that the mechanism underlying both the list length effect and the presentation duration effect here (at short intervals) is the same. Specifically, activation is the source of both effects. Activation is a mechanism; another empirical effect is not.

Further, we believe this potential objection misses the point that encoding is an underspecified term and does not represent an all-or-none process. Words can be apprehended to different degrees, and even words that are not consciously processed can be shown to influence cognitive processing (e.g., Balota, 1983; Marcel, 1980). The semantic priming literature contains numerous reports showing that even words that are flashed too briefly to be reported enter the system at some level. Importantly, the longer the words are shown, the more information is acquired (Balota & Duchek, 1988; Neely, 1976). This effect may result from the conscious apprehension of more list words and/or the extraction of more semantic information from those words not consciously apprehended. In sum, we view activation processes as the source of the increase in false recall as a function of presentation duration (and of the list length effect).

One final issue we wish to address with respect to activation is the following: Although activation has typically been examined with respect to encoding processes, there is no necessary alignment between activation and encoding. Activation can influence retrieval processes, too, although attempts to demonstrate this point empirically within this paradigm have not met with great success (Roediger, McDermott, & Marsh, 2001). In sum, there is at least a logical possibility that semantic activation plays a role during both encoding and retrieval phases.

Monitoring. In addition to the importance of activation processes, our work has pointed toward the importance of a much more strategic, controlled process (or set of processes). These processes, which we have often referred to as “monitoring” processes (or attentional control processes or strategic processes), can influence whether activation is translated into a later false memory. At this point, we are referring to monitoring as representing a single concept with multiple subprocesses, but we expect that future work will necessitate further refinement of our terms. For example, monitoring (like activation) can take place during encoding or retrieval. During encoding people must differentiate between what occurs in the environment and the thoughts aroused by external events. During retrieval, monitoring involves such processes as disentangling prior thoughts from prior overt experience. That is, people must decide whether an activated concept refers to a previously encountered event. Although this specific activation/monitoring framework has a different cast than some of the existing theories and frameworks of false memories, the monitoring component of this framework draws heavily from existing theories, including the source monitoring framework (Johnson & Raye, 1981; Johnson, Hashtroudi, & Lindsay, 1993), dual-process theories of recognition (Atkinson & Juola, 1973; Mandler, 1980), the attributional approach to memory (Jacoby, Kelley, & Dywan, 1989), and the logic of opposition (Jacoby, 1991; Lindsay, 1990).

What is the evidence that people can use strategic monitoring processes to influence the likelihood of false recall and false recognition in this paradigm? Initial evidence came in the form of multiple study-test trials; McDermott (1996) showed that when given a list of 45 words (3 sets of 15 associates), people were able to attenuate the probability of false recall across five study-test opportunities. As they learned the words in the list, they also learned which words were not in the list. Kensinger and Schacter (1999) further showed that older adults, who are thought to suffer from difficulties in monitoring processes (Hasher & Zacks, 1988), are unable to take advantage of the multiple study-test trials. Converging evidence comes from the finding that older adults tend to produce slightly greater levels of false recall than young adults (Balota et al., 1999; Norman & Schacter, 1997).

Informing people about the false recognition effect before the encoding phase and instructing them to attempt to avoid falling prey to recognizing related, nonpresented words also allows people to attenuate (but not eliminate) the effect (Gallo, Roberts, & Seamon, 1997; McDermott & Roediger, 1998). However, Gallo, Roediger, and McDermott (in press) have shown that warning people after the encoding phase and before the test phase does not produce a selective attenuation in false recognition. It appears that the strategic control processes facilitated by the warning instruction take place largely during the encoding phase; providing warning instructions during the test phase alone was not sufficient to reduce the effect.

Watson, McDermott, and Balota (2001) have recently shown that a combination of warnings and multiple study-test opportunities allows young adults to almost eliminate false recall. However, older adults are unable to do so, and even when fully informed about the nature of the experiment and asked not to fall prey to false recall, they are still unable to attenuate false recall with practice. Unlike young adults, older adults are unable to take full advantage of the synergistic effect of two aids to the monitoring process (being fully informed and given practice).

The present results fit cleanly into this activation/monitoring framework. At the shorter presentation durations, activation builds up with increasing duration (as does false recall); at longer durations (e.g., 1 s or more), however, subjects begin to invoke strategies that can oppose the effects of spreading activation. We believe our data highlight the importance of both processes. Benjamin (in press) has also demonstrated the need for a two-process theory within a single experiment. He presented lists to subjects either once or three times and then gave them a free choice recognition test under one of two conditions: a deadline condition, in which a response had to be made within 750 ms; and a no deadline condition, in which people were allowed as much time as necessary to provide their response. He obtained a crossover interaction such that when there was no time pressure, people were able to invoke attentional control to suppress false recognition in the three presentation condition relative to the one presentation condition. However, when placed under time pressure, the monitoring process broke down, and the increased familiarity or activation of the critical items in the three presentation condition resulted in an enhanced probability of false recognition (relative to the one presentation condition). Virtually identical data were obtained when an age manipulation was substituted for the deadline independent variable. Young adults were able to use controlled processes to override the additional activation arising from three presentations (relative to one presentation); however, older adults, who are thought to have deficits in attentional control, demonstrated the opposite pattern: enhanced false recognition following three presentations (relative to a single presentation).

Unresolved issues. Because we are leaving open the possibility that activation and monitoring play roles during both encoding and retrieval, further specification of these processes will be necessary. An additional, complicating issue involves the role of conscious arousal (or activation, or generation, or rehearsal) of the critical nonpresented word. McDermott (1997) showed that perceptual priming is obtained for the critical nonpresented items and argued that such priming was probably caused by conscious thought of the critical nonpresented word during encoding (not for all lists, but with some probability). Roediger and McDermott (1995) made a similar point with respect to *remember* judgments; the reason people report recollecting specific aspects of the presentation of critical nonpresented words may be that they are confusing what they recollect having thought with what they heard (essentially a reality monitoring confusion; see Johnson & Raye, 1981). Whether (and when) conscious rehearsal of the nonpresented word is a result of strategic, elaborative processing (e.g., those brought about by the intent to remember) or whether simple semantic activation can be sufficient to bring about conscious thought of the critical nonpresented word is an open question.

Finally, we acknowledge that the evidence for the importance of activation in producing false memories outpaces our understanding of exactly how this process exerts its effect. We have reviewed the evidence that semantic activation plays an important role, and we believe this evidence is compelling. Nonetheless, there are unresolved problems with this account. For example, semantic activation is thought to be short-lived (although perhaps not as short-lived as originally thought; Balota & Paul, 1996; Chumbley & Balota, 1984; Becker, Moscovitch, Behrmann, & Joordens, 1997). However, false recall and false recognition induced by lists of semantic associates has been observed after delays as long as 1 to 3 weeks (Thapar & McDermott, in press; Toglia, Neuschatz, & Goodwin, 1999), which are long after semantic activation is thought to persist. It may be that an extraction or inferential process operates on the activated information to allow it to persist over time (cf. Bartlett, 1932; Bransford & Franks, 1971; Reyna & Brainerd, 1995), although we have no direct evidence for such a process.

One might also wonder whether the finding that level of processing can exert powerful effects on the probability of false recall and recognition (e.g., Rhodes & Anastasi, 2000; Thapar & McDermott, in press) is problematic for an activation account. One possible answer is that although semantic activation was originally thought to be automatic (Posner & Snyder, 1975), it has been shown that activation can be sensitive to strategic effects (Balota, Black, & Cheney, 1992). That is, activation and elaborative, attentional processes do not operate independently; rather, attentional processes can exert an influence on activation. Another possible explanation is that activation created during the test phase plays a role in producing these effects. Yet a third possibility is that it is the monitoring component (and not the activation component) that is affected by a level-of-processing manipulation. That is, elaboration upon meaning (and indeed any process that encourages abstract, generative, or relational processing) diverts attention from monitoring the objective events and thus may be thought to enhance the constructive nature of later recall (by interfering with the monitoring process). In sum, not all of the existing empirical findings align themselves naturally within the dual-process framework proposed here; further conceptual development is needed before we have a complete understanding of these phenomena.

In summary, we believe that postulating a single process (whether it be encoding-related, e.g., in the form of gist-based processing, Reyna & Brainerd, 1995; or retrieval-related, e.g., in the form of a simple strategic criterion shift, Miller & Wolford, 1999) oversimplifies the phenomenon of associatively-induced false memories. Single-process theories cannot account for the present data or the emerging literature on this topic. We believe, however, that some variant of the dual-process approach proposed here can accommodate the findings in the present experiment, in addition to much of the literature on associatively induced false memories.

Phonologically Associated Lists

Thus far, our discussion has focused on the semantic lists, for which there is a large emerging literature to help frame interpretation of these findings. Only a few articles are directly relevant to our phonologically induced false recall (although false recognition of phonological associates has received some attention; Schacter, Verfaellie, & Anes, 1997; Wallace, 1968; Wallace, Stewart, & Malone, 1995; Wallace, Stewart, Sherman, & Mellor, 1995).

On the basis of the Neighborhood Activation Model (NAM; Luce & Pisoni, 1998), Sommers and Lewis (1999) predicted that phonologically induced false recall would occur and would show patterns similar to those exhibited by semantic lists. The NAM holds that the mental lexicon is organized not only with respect to semantics but also according to the phonological similarity between words. Words that are phonologically similar are said to be in the same phonological neighborhood. The phonological neighborhood of any given word is operationally defined by identifying all other words that can be created by the substitution, addition, or subtraction of a single phoneme. The NAM holds that when a word is heard, all the members of its neighborhood are activated, much like the spread of activation model posits spread through a semantic network. Although the NAM was designed to explain spoken word recognition (and Sommers & Lewis used auditorily presented words), it seemed a reasonable hypothesis that the NAM may apply to visually presented words as well when the phonological features of words are made salient by the presentation of many phonologically related words.

The present data might seem to conflict with a buildup-of-activation account of phonologically induced false recall because we have shown consistent declines across all presentation durations. That is, if a buildup in activation were important in eliciting false recall, one would expect increases in false recall with increasing presentation durations (at least to a certain point), much like the pattern seen with the semantic lists in the present data and in Roediger, Robinson, and Balota (2001). One (admittedly post hoc) possible explanation is that activation for phonological information has been argued to build up and dissipate rapidly such that the window of opportunity to observe phonological priming is much earlier than that for semantic priming (Lukatela & Turvery, 1994a, 1994b). This argument suggests that if one were able to present words at an even faster duration than was used here, it might be possible to observe the upturn in the curve (i.e., an increase in false recall as presentation duration increases). Future research may be able to address this possibility, although, as discussed below, there may be complicating factors.

Why was the probability of false recall so high in the 20-ms condition? One possibility is that the illusion obtained may not have represented a memory illusion but instead a perceptual illusion, akin to illusory conjunctions that have been studied in the object perception domain (Treisman & Schmidt, 1982). That is, under conditions of limited attention and degraded presentation, features of objects can combine such that a new object seems to emerge. Treisman and Souther (1986) found this phenomenon with words, as well. When subjects were asked to try to detect a target word (e.g., *but*) in a quickly presented (e.g., 200 ms) simultaneous display of four three-letter words that were phonologically similar to the target but did not contain the target (e.g., *bud*, *bug*, *bun*, and *bus*), subjects often reported having seen the nonpresented, yet similar, word. Treisman and Souther argued that an illusory recombination of letters took place such that subjects inaccurately perceived the target word. Although we took steps to avoid such an effect by alternating between lowercase and uppercase words within lists, we believe that this illusory conjunction effect may have occurred in the 20-ms phonological condition of our experiment. This seems especially probable because our words were presented in the center of the screen. Therefore, when *sleep* is critical word, *sl* tends to be at the beginning of the word for many of its neighbors (and in the identical spatial location for all five-letter words) and *eep* at the end for other neighbors (and same location for five-letter words). Therefore, visual persistence or iconic memory may be playing a role here in eliciting illusory conjunctions, or visual illusions.

Apart from the 20-ms condition, the data from the semantic and phonological lists are remarkably similar (see Fig. 1). Further, the serial position functions are largely similar (see Fig. 2), except for a main effect of list type (in accurate recall) and (again) the obvious differences seen at 20 ms. Also, output position analysis suggests that false recall tended to be fairly nonsystematic for both types of lists, although not strictly so; there was a suggestion that false recall tended to occur toward the end of the output sequence, and this finding was more pronounced for the semantic lists than the phonological lists. Therefore, although semantically and phonologically induced false recall cannot be argued to be driven by identical mechanisms, we tentatively conclude that many of the same factors are at work in producing semantic and phonological false memories.

CONCLUDING REMARKS

Researchers have been pursuing the question of why some variables produce similar effects on accurate and false recall (as induced by semantically associated lists), whereas other variables produce opposite effects on accurate and false recall. McDermott (1996) argued that an understanding of these patterns will be the key in uncovering the processes underlying these false recall effects. In the present experiment, we have gone further and shown that a single variable can both increase and decrease the probability of false recall. That is, presentation duration can elicit patterns of results such that accurate and false recall vary positively and negatively with each other. This finding constrains theoretical interpretations of false recall in that it implicates more than one factor influencing the illusion. We have proposed two factors (activation and monitoring) that we believe are critical in explaining false recall, and we believe each of them is important to varying degrees in different situations. Future studies may help elucidate the importance of these factors and the interactions between them and lead to better specified classification of the relevant processes that influence the production of false memories.

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