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Effects of delay and number of related list items on implicit activation for DRM critical items in a speeded naming task

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ABSTRACT

Two experiments examined decay and additivity of semantic priming produced by DRM false memory lists on a naming task. Subjects were presented with study lists containing 14 DRM items that were either all 14 related, the first 7 related, the second 7 related, or all 14 unrelated to the non-presented critical item. Priming was measured on a naming task that presented the critical item in test position 1, 3, or 9. Priming occurred for the 14 related list in the first position only. However, there was also evidence for long term semantic priming in other conditions that was not due to relatedness-checking. Across experiments, an underadditive pattern of activation was obtained. The results are interpreted within the context of Activation Monitoring Theory and suggest that the laws of rapid decay and additivity established for single prime target pairs may not apply to mixed DRM lists or delayed testing.

Introduction

Research using the Deese, Roediger, McDermott (DRM) false memory paradigm has established that when subjects are presented with a list of semantic associates (e.g. bed, rest, awake, tired, dream, wake, snooze, blanket, doze, slumber, snore, nap, peace, yawn, drowsy) all converging on a non-presented critical item (e.g. sleep), they often falsely remember the critical item as having been presented in the study list (Deese, 1959; Roediger & McDermott, 1995; see Gallo (2006) for a review). The theoretical explanation of the DRM memory illusion most relevant to the current paper is the Activation Monitoring Theory, which suggests that false memories arise due to a combination of spreading activation and a more controlled monitoring process (Roediger, Balota, & Watson, 2001). A spreading activation mechanism assumes that studying a DRM list activates the semantic representation of each studied item, and this activation also spreads to items related to the study items (cf. Underwood, 1965). Because DRM study lists were created to converge on the critical item, the critical item receives a boost in activation spreading from each of the studied items, thus resulting in a high level of activation. Consistent with Johnson, Hastroudi, and Lindsay's (1993) theory of source monitoring, subjects rely on a monitoring process to determine the source of items with heightened activation; false memories therefore arise when subjects mistakenly attribute the heightened activation of a critical item to prior study. Research has established strong support for the Activation Monitoring Theory (see Meade, Watson, Balota, and Roediger (2007) for a review of research supporting the Activation Monitoring Theory; see Gallo (2006) for a review of Activation Monitoring Theory along with discussion of alternate theories). Critical to the current project is the Activation Monitoring Theory's assumption that implicit activation plays a role in false memory and, as suggested by Tse and Neely (2005), activation processes may be separated out from monitoring processes.

The purpose of the current paper is to further specify the nature of presumed activation underlying the DRM false memory illusion by examining whether activation

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of critical items in the DRM paradigm (in which 15 or so words serve as primes) follows the same laws regarding decay and additivity that have been established in semantic priming studies, which typically use only 1–2 words as primes. Semantic priming refers to the finding that a target word is processed more quickly when it is preceded by a related word relative to when it is preceded by an unrelated word (Meyer & Schvaneveldt, 1971), presumably because activation spreads between linked, related concepts in semantic memory (Collins & Loftus, 1975). Research on semantic priming has largely supported the validity of a spreading activation mechanism (Neely, 1991; see McNamara (2005), for a review; but see Bodner and Masson (2003) and Ratcliff and McKoon (1994) for alternative accounts of semantic priming) and has further established that such activation decays rapidly (Masson, 1995; Neely, 1977) and additively summates from two primes converging on a target (Balota & Paul, 1996). Critically, however, semantic priming is typically measured as the facilitation of a target resulting from a single prime. Because critical item priming following presentation of DRM lists involves a greater number of prime words all converging on the critical item, it is possible that the many converging primes may differentially impact decay rates and additivity of semantic priming for critical items.

Some evidence suggests that DRM lists do indeed elicit activation-based priming of the critical item, as measured on implicit memory tests of word stem completion (McDermott, 1997; McKone & Murphy, 2000), word fragment completion (McDermott, 1997), and anagram tasks (Lovden & Johansson, 2003, though see McBride, Coane, and Raulerson (2006) for an exception; and Tse and Neely (2005), for a discussion of possible explicit memory contamination on the word production tasks used in such studies). The current study builds upon these previous reports of priming from DRM lists to examine two important parameters of semantic priming effects, decay and additivity, that may further inform the nature of activation resulting from converging DRM associates.

Decay

Semantic priming effects have been shown to be short lived so that any facilitation on the target is greatly or completely diminished within a few seconds or with even 1 item intervening between the prime and the target (Dannenbring & Briand, 1982; Masson, 1995). One notable exception is the rare finding of long term semantic priming. Joordens, Becker, and colleagues (Becker, Moscovitch, Behrmann, & Joordens, 1997; Joordens & Becker, 1997; see too Ray & Bly, 2007) have demonstrated that semantic priming effects persist across several seconds and multiple intervening items when the prime(s) and target share semantic features and are tested on tasks that encourage reliance on such features. As suggested by Tse and Neely (2005, 2007), due to the fact that DRM lists include multiple, semantically related primes converging on a single critical item, it is possible the activation produced by DRM lists may last longer than that produced by single primes (see Tse and Neely (2007) for a review of long term semantic priming and evidence of long term semantic priming for DRM items resulting from both multiple and single primes).

The importance of decay in understanding the activation resulting from DRM lists is exemplified in prior research using lexical decision tasks. Lexical decision tasks require subjects to make a word or non word decision and makes no reference to the study episode (Zeelenberg & Pecher, 2002) and so may minimize any contamination from explicit memory (Meade et al., 2007; Tse & Neely, 2005). Consistent with the idea that activation from DRM lists decays over time, studies that present several DRM lists followed by a final lexical decision test do not find evidence of critical item priming (McKone, 2004; Zeelenberg & Pecher, 2002), possibly because any activation from study has decayed before the test was administered (Tse & Neely, 2005). In contrast, studies that present a lexical decision task following each study list have found evidence of critical item priming (Hancock, Hicks, Marsh, & Ritschel, 2003; Meade et al., 2007; Tse & Neely, 2005, 2007), though even among studies employing relatively immediate lexical decision tests following presentation of a single DRM list, there exist differences in the duration of priming.

Tse and Neely (2005) presented subjects with a 14-item DRM list, a 30 s filler task, then a 40-item lexical decision test where the critical item occurred among the first 20 items (first half) or the second 20 items (second half) (this was a conceptual replication of Hancock et al. (2003), but with a different baseline comparison plus several extensions). In three of four experiments, Tse and Neely obtained evidence of semantic priming for critical items that persisted into the second half of the lexical decision test, though the magnitude of priming in the second half of the lexical decision test was smaller relative to the first half of the lexical decision test in two of the four experiments, consistent with the concept of decay. Tse and Neely (2007) replicated the long term semantic priming obtained from DRM lists on lexical decision tests and further specified that long term semantic priming effects were not contingent upon within test priming (i.e. an additional boost in activation from related items presented prior to the critical item on the test (cf. Coane & McBride, 2006). Further, they presented evidence that long term semantic priming for critical items may result from a single DRM item, though the duration of single prime long term semantic priming was less than the duration of the multiple prime long term semantic priming. Considered together, Tse and Neely's (2005, 2007) papers both provide evidence that semantic priming on lexical decisions tests from DRM items is relatively long lasting as the effect was found on lexical decision tests following a 30 s filler task delay plus multiple intervening test items.

In contrast, Meade et al. (2007) obtained no evidence of long term semantic priming on lexical decision tests from DRM lists. Subjects studied 27 item lists containing 15 DRM items interspersed with unrelated words and nonwords (specifically 4 filler words and nonwords were presented first followed by DRM items 1–5, 4 more fillers, DRM items 6–10, 4 fillers, then finally DRM items 11–15). After a 1 s cue to respond, subjects were presented with a lexical decision test that contained the critical item in test position 1, 3, 6, or 11. Semantic priming obtained for the critical item when it was in test position 1, but was gone by test position 3, though false recognition (as measured on a speeded recognition test, not discussed here) remained high across test positions. They concluded that priming on lexical decision from DRM lists was very short lived, lasting just over a second and completely gone with two intervening items.

The studies above are conceptually similar in suggesting that activation decays across time, but the marked difference between studies in the time course of decay warrants further examination. As suggested by Meade et al. (2007) one possibility for the discrepant time course of activation may be that the nature of the study lists encouraged retrospective checking in the Tse and Neely studies thus inflating any effects of semantic activation. Retrospective checking on lexical decision tests suggests that subjects can rely on the relationship between prime and target words to aid lexical decisions (Neely, 1991; Neely, Keefe, & Ross, 1989). In studies testing priming following the study of DRM lists, if only words were studied, then subjects may rely on the relationship between a test word and studied items to speed their response that the test item is a word. Tse and Neely (2005) argued that subjects were unlikely to rely on this strategy because the lexical decision test contained a very low proportion of words related to the study list, the task was speeded, and data indicated subjects were not increasingly aware of study test relationships across trials. However, if subjects did use the strategy, it may have aided priming in Tse and Neely's studies. In contrast, Meade et al. ensured that utilizing a retrospective checking strategy would not aid subjects' responses by including nonwords in the study list (thus rendering the strategy useless since study status was not predictive of lexical status). Of course, as acknowledged by Meade et al. (see too Tse & Neely, 2005, 2007), interspersing nonwords and filler words between blocks of DRM items may have resulted in less activation of the critical item, thus requiring a shorter time interval to decay to zero. Based on previous research then, it remains unclear if the difference in the time course of activation on lexical decision tests is the result of differential reliance on post lexical strategies and/or the nature of the study list presentation (DRM items blocked vs. DRM items interspersed with unrelated words and nonwords).

In the current study, we employed a naming task, which allows a blocked presentation of DRM lists without worry of any reliance on a post lexical strategy. Naming tasks require subjects to say aloud, or name, items presented to them as quickly as possible. Naming tasks have been shown to elicit reliable levels of priming (Hutchison, Balota, Cortese, & Watson, 2008) and critically do not benefit from any type of post lexical strategy (Balota & Lorch, 1986). Specifically, though knowledge that a test item is related to studied items would determine the test item's lexicality, such knowledge would not help one pronounce it. To our knowledge, the current study is the first to measure the time course of priming resulting from intact, or blocked DRM lists on a test that eliminates any retrospective strategy at retrieval. Accordingly, our findings may help determine the relative influence of strategies and list presentation on the decay rates of activation resulting from DRM lists. If reliance on strategy is inflating priming effects across test positions, our naming results should be consistent with Meade et al. (2007) who presumably eliminated retrospective checking by including studied nonwords – namely that priming will be evident when the critical item appears early in the test list, but will rapidly decay. On the other hand if interspersing DRM items with filler items minimizes priming effects across test positions, our naming results should be more consistent with Tse and Neely (2005, 2007), who presented blocked DRM lists and demonstrated persistent priming across test positions. Of course we acknowledge both post lexical strategies and list presentation may influence priming results and further that task demands may differ between lexical decision tests and naming.

Additivity

The semantic priming literature has established multiple prime additivity, by demonstrating that two primes each related to a single target show priming equivalent to the sum of priming obtained for each individual prime target pair. Balota and Paul (1996) presented subjects with two primes that were either both related to the target (RR), both unrelated to the target (UU), or with one related and one unrelated to the target (UR and RU). Priming for the two related primes equaled the sum of the 2 conditions that each contained a single related prime. As noted by Balota and Paul, patterns of additivity may have important implications regarding the processes underlying semantic priming. Additive effects suggest that target activation resulting from a single prime is added to the target activation resulting from an additional prime. Underadditive effects suggest that target activation has reached some maximal threshold from a single prime so that no additional activation boost is obtained from an additional prime. Overadditive effects suggest there may be a "convergence of activation" (Balota & Paul, 1996, p. 828) such that the total target activation is greater than the simple sum of activation resulting from each prime. Extending the logic outlined by Balota and Paul for two primes to the 14 converging primes from DRM lists used in the current study, the current study seeks to determine if critical item priming from 14-item lists is equivalent to the priming produced by the first 7 items plus the priming produced from the second 7 items and further if additivity is consistent across test positions.

Additivity is directly relevant to Activation Monitoring Theory as Roediger et al. (2001) review evidence suggesting that for explicit memory tasks, the greater the associative strength between list item and the critical item, the greater the likelihood of false memories in the DRM paradigm (see too Roediger, Watson, McDermott, & Gallo, 2001). Specifically, Robinson and Roediger (1997) presented subjects with study lists containing different numbers of DRM items (though list length was equated in their second experiment by conversely varying the number of fillers to the number of DRM items). False recall was best predicted by summing the associative strength of study items which suggests activation from DRM items may indeed be additive (though see Watson, Balota, and Roediger (2003) for evidence that DRM items combined with phonological neighbors produce an overadditive effect on explicit memory tests of false recall). Critically, previous research has explored additivity of DRM items on tests of explicit memory while the current study focuses on the summation of implicit activation produced by DRM lists and any changes in additivity across decay (see Meade et al. (2007) for a discussion regarding the relationship between patterns of implicit activation produced by DRM lists and the probability of false memory on an explicit recognition test).

This test of additivity is also relevant to better understanding the time course of decay, as the mixed presentation of DRM and filler items in Meade et al. may have resulted in the bulk of the priming effect resulting from just the final few items of the test list (which were the 5 weakest associates on each DRM list). That is, rather than the possibility that the overall level of activation was reduced by the mixed presentation of study lists, any activation from earlier items in the study list may have decayed by the time the last 5 items were presented so that priming was based exclusively on the last 5 items. Presumably, priming from the weakest 5 associates should be less than priming from all 14 associates, which again would result in a lower level of activation that requires less time to decay to nonexistent levels. To examine whether priming is indeed solely due to the last items in the list, the current experiment divided the study lists into two blocks of 7 items each and we manipulated what preceded the final block of DRM items. In this way, we could directly compare the magnitude of priming effects resulting from the last 7 items in the DRM list when they were preceded by the first 7 items from the same DRM list relative to when they were preceded by the first 7 items from an unrelated DRM list.

To our knowledge, the current study is the first to test the additivity of implicit activation resulting from multiple primes converging on a single DRM critical item. Further, we provide the first test of multiple prime additivity across test positions. Consistent with the work by Balota and Paul (1996) demonstrating prime additivity for short delays between prime and target and the assumptions of Activation Monitoring Theory outlined by Roediger et al. (2001), we predict multiple prime additivity to occur when the critical item is in test position one. There is little if any previous data to inform hypotheses regarding additivity across test positions, but one possibility may be that additivity does not persist across test positions if priming across such delays is due to something other than activation persisting from the study episode.

The current study extends previous research by examining decay and additivity of priming from DRM lists on a naming task. We present subjects with 14-item DRM lists where all items are related to the critical item, only the first 7 items are related to the critical item, only the second 7 items are related to the critical item, or none of the items are related to the critical item. Of interest is how quickly priming effects decay, and whether or not multiple prime additivity is obtained across test positions.

Experiment 1

Methods

Subjects

Subjects were 223 undergraduate students from Montana State University who participated in the experiment as a partial fulfillment of a course requirement. This large number of subjects was needed because (a) reaction time data is highly variable and (b) there were 12 critical conditions in the study and only 24 total lists (creating only two observations per condition per subject). All subjects were native English speakers with normal or corrected-to-normal vision. The data from seven subjects were not analyzed due to missing data in at least 1 condition.

Design

The experiment consisted of a 4 $\times$ 3 within-subjects design. Prime relatedeness (14 related, first 7 related, last 7 related, or 14 unrelated) and test position of the critical item on the naming test (1, 3, or 9) were manipulated within-subjects. The primary dependent variable was the reaction time of subjects' responses on the naming test.

Materials

Study lists were constructed by selecting the top 14 associates from the 48 DRM lists used in Meade et al. (2007); originally selected from Stadler, Roediger, and McDermott (1999) and Watson et al. (2003)) and splitting each list into two groups of items (one group contained items 1–7 from the DRM lists and the other group contained items 8–14). Pairs of DRM lists (designated list A and B) were then used to construct the following four versions of each study list: (1) items 1–14 from DRM list A (14 related condition), (2) items 1–7 from DRM list A, items 8–14 from DRM list B (first 7 related condition), (3) items 1–7 from DRM list B, items 8–14 from DRM list A (last 7 related condition), (4) items 1–14 from study list B (unrelated condition). A sample study list (and tests lists, discussed below) are presented in the Appendix.

The mean backward associative strength for each list, computed using The University of South Florida Word Association norms (Nelson, McEvoy, & Schreiber, 1999), revealed a mean backward associative strength of .189 from all 14 related words to the critical item, .251 from the first 7 (strongest) associates to the critical item, and .127 from the last 7 (weakest) associates to the critical item. Latent semantic analyses were also conducted to determine list-to-critical item and within-list inter-item similarity (Landauer & Dumais, 1997). The mean latent semantic analysis similarity of the entire list to the critical item was .654 for lists in the 14 related condition, .506 for lists the first 7 related condition, .377 for lists in the last 7 related condition, and .149 for lists in the 14 unrelated condition. The mean latent semantic analysis inter-item similarity within lists was .292 for lists in the 14 related condition, and .212 for both the first 7 related condition and last 7 related condition.

Each naming test included 12 items: One critical lure and 11 unrelated filler items matched to the critical items on length and log HAL frequency via the English Lexicon Project (Balota et al., 2002). Three versions of each test list were created so that the critical item appeared in test position 1, 3, or 9.

Procedure

The procedure was similar to the procedure reported by Meade et al. (2007). Subjects individually completed 24 study test blocks. During study, subjects were visually presented with a study list at a rate of 1.5 s/word with a 500 ms inter-stimulus interval (isi) and asked to pay attention to each item in preparation for a later memory test (no memory test actually occurred). Study lists were blocked and items were presented in order of associative strength, so that subjects saw DRM items 1–7 of a given list followed by items 8–14 of the same or a different list. [Note associative strength was counterbalanced across conditions in Experiment 2.] Following presentation of the study list, subjects were given the following cue the naming task was about to begin: the computer played an auditory signal for 1 s while asterisks appeared on the computer screen. The asterisks then disappeared and the first item on the naming task appeared. Subjects were asked to say the word aloud into a microphone as quickly and accurately as possible. Once the microphone detected a response, the initial word was removed and replaced by the next item on the naming task until all 12 items had been presented. Following each study test block, the subjects were cued to press the "s" key to begin a new study list and the next study phase began. Subjects first completed 2 practice study test blocks followed by 24 experimental study test blocks. Following completion of 24 experimental blocks, subjects were thanked for their participation and fully debriefed.

Results

Subjects' reaction times (RTs) less than 100 ms or greater than 1500 ms were considered microphone errors and excluded from all analyses (2.3% of the data). From the remaining RTs, a separate mean and standard deviation were computed for each subject. Outliers in both tasks were removed with the modified nonrecursive procedure suggested by Van Selst and Jolicoeur (1994). This procedure removed an additional 2.2% of the RTs. Priming effects were computed by subtracting the mean RT to target words in each of the three related conditions (first 7 related, last 7 related, all 14 related) from target words in the unrelated condition.

Group means calculated on the basis of individual subjects' trimmed-mean RTs are presented in the top half of Table 1. Unless otherwise noted, each effect called statistically significant is associated with a two-tailed $p < .05$ and all post hoc t-tests use the least significant difference (lsd) procedure (Fisher, 1951). RTs were analyzed with the general linear model, with within-subjects factors of test position (1, 3, or 9) and Relatedness (14 related, first 7 related, last 7 related, or unrelated).

There was an overall effect of test position [$F(2, 430) = 272.76$, $MSE = 6469$], with subjects responding slowest to targets presented in position 1 and fastest to targets presented in position 3. Post hoc t-tests confirmed that subjects' RTs significantly differed across all three test positions. In addition, RTs differed as a function of relatedness [$F(3, 645) = 2.99$, $MSE = 2841$]. Post hoc t-tests comparing each of the three relatedness conditions to the unrelated condition revealed significant priming for both the all 14 related and first 7 related conditions. Priming was marginal for the last 7 related condition ($p < .07$). Finally, the predicted linear decline in priming across test position did not reach significance ($p > .13$).

An additional analysis was conducted to examine possible additivity in priming effects (i.e., all 14 related priming = first 7 priming + last 7 priming) by comparing the priming effect for the 14 related condition (unrelated – all 14 related) to the sum of priming obtained from the first 7 related condition (unrelated – first 7 related) plus priming obtained from the last 7 related condition (unrelated – last 7 related). As discussed previously, such additivity has been demonstrated for multiple prime experiments in a semantic priming task (Balota & Paul, 1996) and is assumed to occur during study of DRM lists as well (see Roediger et al. (2001)). Overall, the pattern of priming effects across conditions was underadditive (i.e., all 14 related < first 7 priming + last 7 priming) and this underadditivity approached significance ($p < .09$). As can be seen in the top half of Table 1 (last column), the mean priming for the all 14 related condition was 7 ± 8 ms smaller than what would be predicted assuming additivity or "summation" in priming effects across the two halves of a related list. [Hereafter, when reporting a $X \pm Y$ ms effect, Y refers to the 95 % confidence interval.] This marginal underadditivity effect did not differ significantly across test positions ($F < 1$).

Table 1
Mean reaction times (in ms) on a speeded naming test for critical words unrelated to the studied words, related to the first 7 studied words, related to the last 7 studied words, or related to all 14 studied words as a function of test position in Experiments 1 and 2.

Relatedness condition	Test position 1 M	1 SE	3 M	3 SE	9 M	9 SE	Mean
Experiment 1: strong items first							
Unrelated	546	7	462	5	469	5	492
First 7 related	538	8	452	5	462	5	484
Last 7 related	540	7	453	5	466	5	486
All 14 related	533	7	456	5	468	5	486
First 7 priming	8		10*		7**		8*
Last 7 priming	6		9*		3		6**
All 14 priming	13*		6		1		7*
Mean priming	9**		8*		4		
Experiment 2: strong items last							
Unrelated	549	8	461	5	470	5	493
First 7 related	542	8	453	5	466	6	487
Last 7 related	538	8	456	5	464	5	486
All 14 related	538	8	459	6	468	5	488
First 7 priming	7		9*		4		7*
Last 7 priming	11*		6		6		8*
All 14 priming	11*		3		2		5*
Mean priming	10		6		4		

* $p < .05$.
** $p < .10$.

Discussion

Obtaining significant priming provides strong evidence for underlying implicit activation of the critical item during study. This is especially true given the current use of a speeded naming task, rather than a lexical decision test. As discussed in the introduction, obtaining critical item priming in a naming task demonstrates that such priming is not reliant on a semantic matching strategy. Interestingly, no interaction was obtained between relatedness and test position suggesting that priming did not decay across test positions. On the face of it, such a finding is contradictory to the relatively short-lived time course of activation obtained by Meade et al. (2007) on lexical decision tests. However, Meade et al. (nor any other studies examining decay of activation from DRM lists) did not include the first 7 related or last 7 related conditions in their experiments, but instead tested only priming following presentation of a single DRM list (as in the current experiment's 14 related condition). In the interest of situating the current results in the context of previous research which has also examined decay of activation from DRM lists, we feel the pattern of decay resulting from the 14 related condition in the current experiment may be important. Specifically, the pattern of data in this condition is numerically consistent with Meade et al.'s finding of significant priming only in test position 1.

Moreover, significant priming in the first 7 related condition demonstrates that critical item activation can persist even across 7 additional study items (14 s total), the naming cue (1 s), and up to 8 naming items (8.8 s, assuming 500 ms RT per item plus 600 ms isi). Such long term semantic priming effects obtained in the first 7 related condition are especially interesting when considered in conjunction with the trend toward underadditivity obtained in the current experiment. Underadditive effects suggest that priming is likely caused by something other than simple spreading activation across related nodes because, had the activation from the first half of the list simply decayed, priming should have been additive (e.g. 0 ms from the first 7 items plus N ms priming from the second 7 items = N ms of additive priming). The current data suggest that subjects are doing something different in the first 7 and last 7 related conditions, relative to all 14 related, which contributes to long term semantic priming and underaddivity. One speculation is that subjects may label or organize one grouping of words once it is clear the topic of the list is changing (this would occur only in the first 7 and last 7 related conditions). We return to this idea in the general discussion.

Experiment 2

The purpose of Experiment 2 was to replicate the findings obtained in Experiment 1 and also to address the possible confound between associative strength and test condition present in Experiment 1. As is typical in DRM research, the study lists in Experiment 1 were presented in order of associative strength so that the strongest associates to the critical item were presented first and the weakest associates were presented last. To ensure that the results of Experiment 1 were not due solely to the fact that items with greater associative strength were always presented first, the study lists in Experiment 2 were modified so that items with the weakest associative strength were presented first. Changing the order of study items was not expected to alter the general pattern of results, though the magnitude of priming in Experiment 2 may increase due to a shorter time delay between presentation of the strongest associates and the naming task. Note that across experiments, the strength of items in the first 7 condition were equated with the associative strength of items in the last 7 condition.

Methods

Subjects

One hundred ninety eight undergraduate students at Montana State University participated in the experiment as a partial fulfillment of a class requirement. All subjects were native English speakers with normal or corrected-to-normal vision. The data from six subjects were not analyzed due to missing data in at least 1 condition.

Design

The design of Experiment 2 was identical to the design of Experiment 1. Again, prime relatedness and critical item test position on the naming task were both manipulated within-subjects. The primary dependent variable was RT on the naming task.

Materials

The study lists used in Experiment 1 were modified to unconfound associative strength with test condition. Specifically, the all 14 related condition now contained items 8–14 followed by items 1–7 of DRM list A, the first 7 related condition consisted of items 8–14 from DRM list A followed by items 1–7 from DRM list B, the last 7 related condition consisted of items 8–14 from DRM list B followed by items 1–7 from DRM list A, and the unrelated condition contained items 8–14 followed by items 1–7 of DRM list B. The test lists used in Experiment 2 were identical to those used in Experiment 1.

Procedure

The procedure of Experiment 2 was identical to the procedure of Experiment 1.

Results

RT data was treated identically to Experiment 1. After removing microphone errors (2.4% of the data), a separate mean and standard deviation were computed for each subject. Using the Van Selst and Jolicoeur (1994) procedure for removing outliers removed an additional 2.2% of the RTs. As with Experiment 1, priming effects were computed by subtracting the mean RT to target words in each of the three related conditions (first 7 related, last 7 related, all 14 related) from target words in the unrelated condition.

Group means calculated on the basis of individual subjects' trimmed-mean RTs are presented in the bottom half of Table 1. Replicating Experiment 1, there was an overall effect of test position, $F(2, 382) = 218.58$, $MSE = 7405$. RTs significantly differed across all three test positions with subjects again responding slowest to targets presented in position 1 and fastest to targets presented in position 3. There was also again a significant overall effect of relatedness [$F(3, 573) = 2.93$, $MSE = 2259$]. Significant priming effects were obtained for all three relatedness conditions, relative to the unrelated condition. Finally, the predicted linear decline in priming across test position again did not reach significance ($p > .38$).

As with Experiment 1, an additional analysis was conducted to examine additivity in priming (i.e., all 14 related priming = first 7 priming + last 7 priming) by comparing the priming effect for the all 14 related condition to the sum of priming obtained for the first 7 related plus last 7 related conditions. As can be seen in the bottom half of Table 1 (last column), there was a significant underadditive pattern of priming [$F(1, 191) = 4.76$, $MSE = 4880$]. The mean priming for the all 14 related condition was 10 ± 8 ms smaller than what would be predicted if priming from the two halves of a related list summated when combined. This underadditivity effect again did not differ significantly across test positions ($F < 1$).

Discussion

The results of Experiment 2 replicated the results of Experiment 1 in demonstrating significant overall priming and no interaction between priming and test position. Priming in the 14 related condition again numerically replicated the findings of Meade et al. (2007). Further, consistent with Experiment 1, priming from the first 7 related condition was significant, demonstrating long term semantic priming from the weakest DRM associates. Experiment 2 also replicated the pattern of underadditivity obtained in Experiment 1. Again, when the long term semantic priming resulting from the first 7 related condition is considered in conjunction with underadditivity, it suggests subjects may be doing something different in the first 7 and last 7 related conditions, relative to all 14 related, which contributes to long term semantic priming. We will discuss this idea further in the general discussion.

General discussion

The current experiments were the first to examine decay and additivity of semantic priming on a naming task resulting from the presentation of blocked DRM lists. Regarding decay of activation, the current study revealed no decay in priming across positions both when the strongest associates were presented first in the study list (Experiment1) and when the weakest associates were presented first in the study list (Experiment 2). Interestingly, significant priming effects resulted from both blocked DRM lists (14 related condition) and mixed DRM lists (consisting of 7 related and 7 unrelated items). Across both experiments, significant priming in the first 7 related condition suggests a relatively long duration of activation resulting from mixed DRM lists.

The current experiments also revealed novel findings regarding the additivity of priming resulting from multiple associates converging on a single critical item. Across experiments, the general finding was underadditivity, suggesting that the priming produced by the 14 related condition was less than would be predicted by summing together the priming produced from the mixed list conditions.

Decay

The current study obtained evidence that priming on a naming task resulted from blocked lists (14 related condition) and mixed DRM lists (first 7 related and last 7 related conditions). Critically, the magnitude of priming did not decay across test positions. This finding is consistent with research demonstrating converging associates processed semantically result in long lasting priming effects (Becker et al., 1997). Also, this finding is consistent with Tse and Neely's (2005, 2007) finding that multiple converging associates from DRM lists produce long lasting activation. However, the finding of no decay across test positions is inconsistent with our a priori hypotheses and is further inconsistent with the few prior research studies that have examined the time course of activation decay resulting from DRM lists. Specifically, though Tse and Neely (2005) and Meade et al. (2007) found marked differences in the specific time course of decay, both studies were in conceptual agreement that activation from DRM lists does decay. One possible explanation for the differences between the current results and prior results is that the task demands involved in naming (used in the current study) differ from the task demands involved in lexical decision (used by both Tse and Neely (2005, 2007) and Meade et al. (2007)) in such a way that the naming task protects against decay. We find this explanation implausible since lexical decision, not naming, has been shown to be more susceptible to artificial enhancement through post lexical strategies (cf. Neely, 1991).

Another more plausible explanation is that the inclusion of both blocked DRM lists (14 related condition) and mixed DRM lists (7 related and 7 unrelated) in our design renders a direct comparison of decay rates difficult. Prior studies examining decay used study lists most similar to the 14 related condition in that they included items from only a single DRM list. In the interest of explaining our results in relation to prior research, we speculate that in fact priming resulting from the 14 related condition in the current study does show some decay (in Experiments 1 and 2 of the current study, priming in the 14 related condition was significant at test position 1, but not at test positions 3 and 9). Thus, findings in the 14 related condition (standard DRM) may be consistent with findings from single prime target pairs showing priming decays rapidly and with few intervening items (Dannenbring & Briand, 1982; Masson, 1995). That is, the implicit activation produced by DRM items decays rapidly just as does implicit activation produced by single-item prime target pairs. Further, the time course of decay obtained with the 14 related condition directly replicates the time course of semantic priming obtained by Meade et al. (2007) who showed that priming on lexical decision tests was diminished by test position 3. Meade et al. suggested that the rapid decay of activation resulting from DRM lists is consistent with the Activation Monitoring Theory. Specifically, during study, DRM items implicitly activate the critical item, and the activation decays rapidly unless subjects think back to the study episode, thus reactivating the network established during study. In this way, long lasting false memory effects (e.g. Meade et al., 2007; Seamon et al., 2002) demonstrate a different time course than the rapid decay of implicit activation because during explicit retrieval, subjects think back to the study episode, thus reactivating the activation network established during study. The results of the current study are consistent with the idea that in the absence of retrieval strategies, implicit activation from DRM lists is short lived.

Significant priming effects in the mixed list conditions (7 related and 7 unrelated) provide tentative evidence for long term semantic priming, a finding consistent with prior studies showing long lasting priming from DRM lists (Tse & Neely, 2005, 2007) and other materials (Becker et al., 1997). We suggest our finding is tentative because the nature of two unrelated blocks of 7 associates presented in the mixed condition may have encouraged subjects to label or identify a theme for the first block once the second block started. Theme identification would occur only when subjects noticed a change in the list (i.e. after having studied 7 related words, subjects should notice that the 8th and subsequent words are unrelated to the block of previously presented items), and so would not be necessary in the 14 related condition, nor would it be necessary at the end of the second block of 7 items, since these conditions involve no switch in theme. Further, subjects may not have had time at the end of the second block of 7 items to identify a theme because the naming task began immediately following the second block. To the extent that the critical item came to mind, it may be that the long term semantic priming in the mixed list condition is reflective of repetition priming, which is typically longer lasting than semantic priming (see Tenpenny (1995), for a review). Some support for this speculation lies in the finding that the first 7 related condition showed long term semantic priming both when the first seven were the strongest associates (Experiment 1) and when the first seven were the weakest associates (Experiment 2); these findings in combination with the (numerically) rapid decay of activation obtained in the 14 related condition implies that the 7 weakest associates produced longer lasting priming effects on their own than in combination with stronger associates. We know of no precedent in the literature for such a finding and so must consider the possibility that repetition priming (produced by conscious identification of the critical item during study) may be influencing our results. Of course, if switching categories during study results in subjects organizing during study, one might question why the mixed study lists used by Meade et al. (2007) did not also produce such an effect. One possible explanation may be that the current study relied on one list block followed by a block from another list. In Meade et al., the list started out with fillers, then proceeded to intersperse blocks of fillers between blocks of items from one list and so the transitions may have been less obvious.

Additivity

Underadditive effects were obtained both when the strongest associates were presented first (Experiment 1) and when the strongest associates were presented last (Experiment 2). Underadditivity suggests there is some maximal threshold of activation beyond which the presentation of additional DRM list items offer no additional boost in activation of the critical item. Such a finding is logical given that DRM list items are designed to converge on the critical item. However, the underadditive pattern of activation obtained in the current study is inconsistent with previous demonstrations of additive (Balota & Paul, 1996) and overadditive (Watson et al., 2003) patterns of activation. Differences between the current study and previous research may be at least partly explained by task differences, namely that subjects in the current study were instructed at study that they would be later tested on their memory for the words, and that each prime was presented for 1500 ms. One additional possible explanation of underaddtivity, as noted above, is that subjects may use a different strategy in the mixed list condition than in all 14 related condition. If this is indeed the case, then the estimate of underadditivity would reflect such strategy use, rather than the degree of implicit activation for the critical item.

In summary, the current study was the first to explore the time course and additivity of spreading activation underlying the blocked presentation of DRM lists on a naming task. Priming occurred for the 14 related list in the first position only. However, priming also occurred for the mixed lists across test positions suggesting long term semantic priming that was not due to relatedness-checking. Further, priming showed an underadditive pattern. These results suggest that the laws regarding decay rates and additivity obtained using single prime targets may not always describe the pattern of activation produced by DRM lists.

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Appendix

Study and test lists for the Critical Lure, Window

A.1. Study lists (Critical Lure Window)

All 14 related: door, glass, pane, shade, ledge, sill, house, open, curtain, frame, view, breeze, sash, screen.
First 7 related: door, glass, pane, shade, ledge, sill, house, wrath, happy, fight, hatred, mean, calm, emotion.
Last 7 related: mad, fear, hate, rage, temper, fury, ire, open, curtain, frame, view, breeze, sash, screen.
Unrelated: mad, fear, hate, rage, temper, fury, ire, wrath, happy, fight, hatred, mean, calm, emotion.

A.2. Test lists (Critical Lure Window)

Related test position 1: window, enter, drill, ranks, yes, eager, ray, yet, due, speak, gene, main.
Unrelated test position 1: anger, enter, drill, ranks, yes, eager, ray, yet, due, speak, gene, main.
Related test position 3: enter, drill, window, ranks, yes, eager, ray, yet, due, speak, gene, main.
Unrelated test position 3: enter, drill, anger, ranks, yes, eager, ray, yet, due, speak, gene, main.
Related test position 9: enter, drill, ranks, yes, eager, ray, yet, due, window, speak, gene, main.
Unrelated test position 9: enter, drill, ranks, yes, eager, ray, yet, due, anger, speak, gene, main.

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