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Activating the critical lure during study is unnecessary for false recognition

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Abstract

Participants studied lists of *nonwords* (e.g., *froost*, *floost*, *stoost*, etc.) that were orthographic-phonologically similar to a nonpresented critical lure, which was also a nonword (e.g., *ploost*). Experiment 1 showed a high level of false recognition for the critical lure. Experiment 2 showed that the false recognition effect was also present for forewarned participants who were informed about the nature of the false recognition effect and told to avoid making false recognition judgments. The present results show that false recognition effects can be obtained even when the critical lure itself is not stored during study. This finding is problematic for accounts that attribute false memories to implicit associative responses or spreading activation but is easily explained by global familiarity models of recognition memory.

Keywords: False recognition; Global Familiarity Models; Nonconscious spreading activation; Orthographic-phonological similarity; Retrieval

1. Introduction

Human memory is not perfect and some conditions can give rise to highly inaccurate memories. One such condition that creates inaccurate memories is the DRM paradigm (Deese, 1959; Roedi-

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ger & McDermott, 1995). In the standard DRM paradigm, participants study lists of words (e.g., *thread*, *pin*, *eye*, etc.) that are semantically related to a nonpresented word, the critical lure (e.g., *needle*). Although the critical lure is not presented during study participants often falsely recognize it in an episodic recognition test. The percent 'old' responses to the critical lure is often as high as or not far below the percent 'old' responses to studied items. Such findings are obtained even for warned participants who are informed about the false memory effect and told not to make such errors (e.g., Gallo, Roediger, & McDermott, 2001). Moreover, participants are usually quite confident that the critical lure was presented during study (e.g., McDermott & Roediger, 1998). Thus, the false recognition effect is quite powerful and robust.

Different explanations for false memories have been proposed. One explanation attributes false memories to implicit associative responses (e.g., Underwood, 1965; also see Lövdén & Johansson, 2003; McDermott, 1997; Roediger & McDermott, 1995). According to this account, when a word is studied a related word may consciously come to mind. For example, presentation of the words *thread*, *pin*, *eye*, etc. during study may elicit the covert verbal response *needle* and, consequently, *needle* may be stored in memory. On a later memory test, participants may think *needle* was actually presented on the study list if they fail to retrieve the correct source of the memory trace for *needle*.

Recently, however, it has been argued that false memories may also be obtained when the critical lure does not consciously come to mind during study. At least two findings have been taken to support this claim. First, false memories have been found when list items are presented for 100 ms or less (e.g., McDermott & Watson, 2001; Seamon, Luo, & Gallo, 1998). At these presentation rates, it has been argued, it is unlikely that the critical lure will consciously come to mind. The second relevant finding was obtained by Seamon et al. (2002) who asked participants to think out loud and say the words that came to mind during study. Although participants spontaneously rehearsed about half the critical lures during study false memories were also found for critical lures that had not been rehearsed during study. Seamon et al. (2002) concluded that thinking of the critical lure was not necessary for producing false memories. Findings such as these have been explained by nonconscious spreading activation (e.g., Roediger, Balota, & Watson, 2002; Seamon et al., 1998). Spreading activation theories (e.g., Collins & Loftus, 1975) assume that when a word is presented activation automatically spreads to related words in a semantic-associative network, resulting in the activation of these words. In the DRM paradigm, multiple words presented during study are related to the nonstudied critical lure. Convergence of the activation spreading from these words may result in a high level of activation of the critical lure even though the critical lure was not presented. Assuming that this high level of activation has a long-lasting effect on memory this could lead to a large false recognition effect.

To summarize, a currently popular view is that false memories can be obtained when the critical lure does not consciously come to mind during study. Instead, false memories may be due to nonconscious activation of the critical lure. In this paper, we take the issue one step further and ask the question whether false memories can be obtained even when the critical lure itself is not activated during study. At first this might seem unlikely but this possibility is suggested by global familiarity or global matching theories of recognition memory such as, for example, TODAM (Murdock, 1982), SAM (Gillund & Shiffrin, 1984), MINERVA2 (Hintzman, 1988) and REM (Shiffrin & Steyvers, 1997). According to global familiarity models (for a review, see Clark & Gronlund, 1996), a recognition judgment is based on the match between the test item and all (list) items in memory. Because the match depends on the similarity between the test item and the items in memory, participants are more likely to make an 'old' recognition judgment if (semantically, orthographically or phonologically) similar items were presented on the study list. In the standard DRM paradigm, many items on the study list are semantically similar to the critical lure and this will result in a relatively strong match between the lure and the items in memory. As a result, participants will be likely to think the critical lure was presented during study.

To be a bit more specific, consider, for example, the REM model for recognition memory (we present a brief verbal description; mathematical details can be found in various sources, e.g., Criss & Shiffrin, 2004; Malmberg, Zeelenberg, & Shiffrin, 2004; Shiffrin & Steyvers, 1997). REM assumes that memory traces consist of features representing orthographic, phonological, semantic and contextual information. When an item is studied features are stored in an episodic memory trace.[1] Recognition judgments are based on a comparison of the test item to the studied list items in episodic memory. The test item is matched in parallel to each memory trace and the system notes the matching and nonmatching features. Feature values in the test item that match corresponding feature values in an episodic trace contribute evidence that an item is old. Mismatching features contribute evidence that an item is new. Based on the matching and mismatching features the system calculates the odds that the test item is old (the odds equal the probability that the test item is old divided by the probability that the test item is new). If the odds exceed the criterion (the default criterion is 1.0, but participants could deviate from this value) an 'old' response is made. False alarms arise when the odds of a nonstudied item exceed the criterion for an 'old' response. This is more likely to happen when items similar to the nonstudied test item have been studied, because in this case there will be relatively many matching features.

An important feature of global familiarity models is that they attribute false recognition to the matching process that takes place during the recognition test. Thus, global familiarity models need not assume that the critical lure was stored during study to account for false recognition. Hence, if we would find a false recognition effect under conditions in which it is unlikely that the critical lure was stored during study this would provide evidence supporting the global familiarity account of false recognition.

2. Experiment 1

To test the prediction that false recognition effects can be obtained even when the critical lure itself is not activated during study, participants studied *nonwords* (e.g., *froost*, *floost*, *stoost*, etc.) that were orthographic-phonologically similar to a nonpresented critical lure (e.g., *ploost*). Global familiarity models predict false recognition for a nonword that is orthographic-phonologically similar to multiple list items because the similarity will result in a relatively strong match between the nonword lure presented at test and the orthographic-phonologically similar nonwords in memory. Previously published studies (e.g., Schacter, Verfaillie, & Anes, 1997; Shiffrin, Huber,

[1] Episodic memory traces are incomplete and error prone. That is, not all features of a stimulus are stored in the episodic trace and those features that are stored, may be stored incorrectly (i.e., an incorrect feature value is stored). The number of features stored and the accuracy with which they are stored depend on a number of factors such as study time, attention, hippocampal lesions, and the influence of psychopharmaca (e.g., Malmberg et al., 2004).

& Marinelli, 1995) have shown that false recognition can be obtained for critical lures (e.g., *fate*) that are orthographic-phonologically (instead of semantically) related to multiple list items (e.g., *hate*, *mate*, etc.). However, these studies have used existing words and activation may spread not only between semantically related words but also between orthographic-phonologically related words (e.g., Collins & Loftus, 1975; Sommers & Lewis, 1999). Therefore, these results do not show that false recognition can be obtained when the critical lure was not activated during study. In the present study, however, we used nonword stimuli. Because nonwords have no representation in lexical-semantic memory it is unlikely that activation will spread from one nonword to another (orthographic-phonologically related) nonword. It is also unlikely that the critical lure will consciously come to mind during study because prior to the test phase the critical lure has never been encountered by the participant. The finding of a false memory effect in the present study would therefore show that false recognition does not rely on the conscious or nonconscious storage of the critical lure during study.

2.1. Method

2.1.1. Participants

The participants were 22 students of the Erasmus University Rotterdam and Leiden University who received course credit or a small monetary reward for their participation. All participants were native speakers of Dutch. None of them had previously participated in a related memory experiment.

2.1.2. Materials and design

The materials consisted of 16 lists of orthographically legal, pronounceable nonwords.[2] Each list consisted of a critical lure (e.g., *ploost*) and 12 list items (e.g., *froost*, *floost*, *stoost*, *koost*, *noost*, *spoost*, *moost*, *soost*, *boost*, *poost*, *broost*, and *droost*) that were all orthographic-phonologically similar to each other and the critical lure. The critical lure was not necessarily the item that was most similar to the other items on the list (i.e., the critical lure was not the 'prototype' or central item). The list items and critical lure differed from the other items on the same list by the addition, deletion or change of one or two letters. All items varied in length from 4 to 8 letters. For counterbalancing purposes the nonword lists were divided into two sets of eight lists, set A and set B. Half of the participants studied set A, the other half studied set B. The same test list was used for all participants, hence items that were targets for one half of the participants were distractors for the other half, and vice versa.

2.1.3. Procedure

Participants were told that they would participate in an experiment that was about memory and were instructed to memorize as many items as possible for an unspecified memory test that would follow at the end of the experiment. No mention was made of the structure of the study list and the fact that many of the items were orthographic-phonologically similar to each other.

[2] Pronunciation of a nonword is straightforward because there is a close correspondence between orthography and phonology in the Dutch language. Similar nonwords have been used in numerous lexical decision studies (e.g., de Groot, Thomassen, & Hudson, 1982; Zeelenberg & Pecher, 2003).

During study, 96 nonwords (8 lists of 12 items) were presented in a randomly intermixed order (e.g., *floost*, *zoes*, *trapel*, *praaf*, *froost*, *bleun*, etc.). The critical lures were never studied. Each nonword was displayed for 3 s and followed by a 500 ms ISI. After presentation of the 96 nonwords, participants were given a recognition test in which they had to judge whether or not a test item had been presented during study. Participants were instructed to respond as accurately as possible and were informed that there was no time limit for responding. The test items consisted of three list items from each of the 16 lists that were used in the experiment, as well as the critical lure belonging to each list. Thus, of the 64 nonwords presented at test, 24 nonwords had been studied, 8 nonwords were the critical lures belonging to the 8 studied lists and the remaining 32 nonwords belonged to the lists that were not studied (24 list items and 8 critical lures). If participants thought they recognized a nonword as a studied item they were instructed to press the m-key of the keyboard ('old' response) and if they did not recognize the nonword as a studied item they were instructed to press the z-key ('new' response). All items in the recognition test were presented in a different random order for each participant and remained on the screen until a response was made.

2.2. Results and discussion

The results of Experiment 1 are summarized in Table 1, which shows the percentage of 'old' responses as a function of study condition. Participants gave an 'old' response to 74.4% of the critical lures from studied lists and to only 17.0% of the critical lures from nonstudied lists. In other words, participant were much more likely to indicate erroneously that the nonword *ploost* had been studied if they had studied *froost*, *floost*, *stoost*, etc. than if they had not studied *froost*, *floost*, *stoost*, etc. This false memory effect was highly significant, $t(21) = 11.37$, $p < .0001$. Participants correctly recognized 86.4% of the list items from studied lists, while the false alarm rate for nonstudied list items was 14.6.%. This veridical memory effect was also significant, $t(21) = 17.58$, $p < .0001$.

The finding of a false memory effect for nonwords that are orthographic-phonologically related to studied nonwords is consistent with the idea that activation of the critical lure during study is not a necessary condition for false recognition effects. In Experiment 2, we wanted to replicate and extend the findings of Experiment 1. False memory effects using the standard DRM paradigm have been obtained under a variety of study and test conditions. Notably, false recognition effects are present even when participants are informed about the nature of false memory experiments and told to avoid false memories (Gallo, Roberts, & Seamon, 1997; Gallo et al., 2001; McDermott & Roediger, 1998). The aim of Experiment 2 was to investigate if the false memory effect that we obtained for nonwords in Experiment 1 would still be present for such forewarned participants.

Table 1
Percentage of 'old' responses in Experiment 1 as a function of study condition

Condition	Studied list	Nonstudied list
Critical lure	74.4	17.0
List item	86.4	14.6

3. Experiment 2

3.1. Method

The participants were 18 students of the Erasmus University Rotterdam who received course credit or a small monetary reward for their participation. All participants were native speakers of Dutch and none of them had previously participated in a related memory experiment.

The materials and procedure were identical to that of Experiment 1, except that prior to the study phase participants were informed about the false memory effect. Participants were told that prior research has shown that participants often show false memories for stimuli that are orthographic-phonologically related to studied list items and were given examples of stimuli that might cause a false memory effect. They were told to avoid making such errors. Immediately before test participants were reminded of the false memory phenomenon and told to respond ‘old’ only to items that were actually presented during study.

3.2. Results and discussion

Table 2 summarizes the results of Experiment 2, displaying the percentage of ‘old’ responses on the recognition test as a function of study condition. Participants gave an ‘old’ response to 58.6% of the critical lures from studied lists and to only 12.5% of the critical lures from nonstudied lists. This false memory effect was again highly significant, $t(17) = 6.48$, $p < .0001$. The difference in the number of ‘old’ responses to studied and nonstudied list items was also significant, $t(17) = 15.54$, $p < .0001$, showing a veridical memory effect. Thus, even though participants were informed about the false memory effect and told to avoid false memories we still obtained a large false memory effect.

The primary aim of Experiment 2 was to determine whether a false recognition effect would still be present in forewarned participants and not to determine exactly how warning participants affects the false memory effect. Nevertheless, it might be interesting to take a closer look at the effect of warning on performance in the recognition test. To compare performance in Experiments 1 and 2, we calculated A', a measure of memory discrimination,[3] and B''_D, a measure of response criterion (Donaldson, 1992). When calculating A' and B''_D for critical lures, an ‘old’ response to a critical lure from a studied list was considered a ‘hit’ and an ‘old’ response to a critical lure from an unstudied list was considered a false alarm. The values of A' and B''_D are displayed in Table 3. For critical lures, A' did not significantly differ between Experiment 1 and Experiment 2, $t(38) = 1.38$, $p > .15$. Likewise, for list items, A' did not significantly differ between Experiment 1 and Experiment 2, $t(38) = 1.30$, $p > .15$. Thus, warning participants did not affect A' for either false or veridical recognition.[4] A different picture was obtained for B''_D. For critical lures, B''_D was significantly higher in Experiment 2 than in Experiment 1, $t(38) = 3.86$, $p < .001$. For list items too, B''_D was significantly higher in Experiment 2 than in Experiment 1, $t(38) = 3.57$, $p < .001$. Thus, it seems that the main effect of forewarning was to make the participants’ recognition response criterion

[3] For critical lures, A' indicates false recognition susceptibility or false recognition strength.

[4] The same result was obtained when we computed d' instead of A'.

Table 2
Percentage of 'old' responses in Experiment 2 as a function of study condition

Condition	Studied list	Nonstudied list
Critical lure	54.2	11.1
List item	71.3	10.0

Table 3
Memory discrimination (A') and response criterion (B''_D) in Experiments 1 and 2

Condition	A'		B''_D	
	CL	LI	CL	LI
Experiment 1: no warning	.86	.91	.20	.01
Experiment 2: forewarning	.81	.89	.85	.58

Note. CL, critical lure; LI, list item.

more conservative. In other words, forewarned participants were overall (i.e., for both critical lures and list items) less likely to make an 'old' response.

It is interesting to note that in terms of A' the false recognition effect was about equally large in Experiments 1 and 2. Previous studies (Gallo et al., 2001; Neuschatz, Benoit, & Payne, 2003) using semantically related lists of words have shown that forewarning participants can sometimes substantially reduce the size of the false recognition effect (although false memories are still present for such forewarned participants). It might be worth speculating why warning was not very effective in our study. One possibility is that participants in our study were not able to identify the critical lure. A recent study by Neuschatz et al. (2003) showed that forewarning was much more effective for high identifiable DRM lists (i.e., lists for which a high proportion of participants can identify the critical lure) than for low identifiable DRM lists. If, during study, participants identify the critical lure and tag it as 'nonpresented' they may use this information at test to withhold an erroneous 'old' response. In our study, however, the critical lure was probably not highly identifiable. Because there is a large number of nonwords that could potentially be the critical lure (remember that the critical lure was not the 'prototype' or central item), the probability of identifying the lure is probably rather small and hence it could not be tagged as 'nonpresented'. Of course this explanation is somewhat speculative and must await further experimentation. The main point of Experiment 2, however, is that even when participants are forewarned false recognition effects are still obtained.

4. General discussion

In two experiments, we investigated false recognition for nonwords that were orthographic-phonologically similar to nonwords presented at study. Experiment 1 showed that participants more often erroneously indicated that they had studied the critical lure (e.g., *ploost*) if they had studied orthographic-phonologically similar list items (e.g., *froost*, *floost*, *stoost*, etc.) than if they had not studied orthographic-phonologically similar list items. Experiment 2 showed that the false recognition effect persisted even for forewarned participants indicating that, like the false recognition effect obtained in the standard DRM paradigm for semantically related lists of words, the false recognition effect for nonwords is powerful and robust.

The results of the present study are predicted by global familiarity models of recognition memory (e.g., Gillund & Shiffrin, 1984; Hintzman, 1988; Murdock, 1982; Shiffrin & Steyvers, 1997). These models assume that the test item is matched in parallel to all studied items in memory. Because the familiarity of the test item depends on the similarity between the test item and the items in memory test items that are similar to multiple studied items will be highly familiar. Hence, participants will be likely to think the test item was studied even though it was not. The present results are more difficult to explain, however, by the implicit associative response account and extant spreading activation accounts, because these accounts assume that the critical lure itself is stored during study. According to the implicit associative response account, false memories occur because the critical lure consciously comes to mind during study of the list items. This seems unlikely to happen, however, for nonwords that have never been encountered by the participant. Likewise, because nonwords do not have representations in lexical-semantic memory it is difficult to see how activation can spread from the list items to the critical lure.[5]

Proponents of the spreading activation account might argue that although the present results are problematic for spreading activation accounts of false recognition they do not show that spreading activation is not responsible for false recognition in the standard DRM paradigm in which participants study lists of words that are semantically related to a nonstudied critical lure. The standard DRM paradigm differs from the present study in that stimuli are semantically related instead of orthographic-phonologically and in that words are used instead of nonwords. It is, of course, possible that different mechanisms are responsible for the false recognition effects for different types of stimuli, but it does not strike us as a very attractive explanation. First, it should be noted that the spreading activation mechanism has been used as an explanation for false recognition of orthographic-phonologically related words (e.g., Roediger et al., 2002; Sommers & Lewis, 1999). Second, and maybe more important, global familiarity models can explain false recognition for different types of stimuli, not only for words and nonwords, but also for other stimuli, such as, for example, faces (e.g., Criss & Shiffrin, 2004). As long as a nonstudied test item is similar to studied list items on a relevant dimension global familiarity models predict a false recognition effect. Thus, global familiarity models provide a simple and parsimonious account of false recognition for different types of stimuli and different types of similarity.

[5] Although the present results cannot be explained by extant spreading activation accounts of false memories, one might argue they could possibly be explained by a modified spreading activation account that assumes sublexical representations (cf. Dorfman, 1994; Treiman, Mullennix, Bijeljac-Babic, & Richmond-Welty, 1995). Such an explanation would have to assume that during study activation converges on sublexical components. If these sublexical components are subsequently accessed during test they may affect memory performance. One important question would be what kind of sublexical components mediate the false memory effect. Since most stimuli used in the present study consisted of a single syllable it is unlikely that the effect is mediated by syllables (or morphemes) common to the stimuli on the lists. The false memory effect could possibly be mediated, however, by orthographic or phonological body units. It should be noted that such an explanation differs from the explanations that have been put forward to explain false memory effects and it remains to be seen whether it can account for orthographic-phonologically based false memory effects (as well as veridical memory effects) for both words and nonwords. Most important for the present study, however, is that such a modified spreading activation account does not assume that the critical lure itself has to be activated to obtain false memory effects and hence it is consistent with the main claim of the present study.

As we mentioned in Section 1, nonconscious spreading activation accounts of false memories have been proposed to explain findings that are supposedly not easily explained by conscious activation of the critical lure during study. One such finding was reported by Seamon et al. (2002) who found false memory effects for lures not rehearsed during study. In another study, Seamon et al. (1998) obtained a false recognition effect with very fast presentation rates during study. According to Seamon and colleagues these results indicate that false memories can be obtained even when the critical lure is not consciously activated during study (but see Raaijmakers & Zeelenberg, 2004; Zeelenberg, Plomp, & Raaijmakers, 2003). But do these results necessitate an explanation in terms of nonconscious storage of the critical lure in memory? The answer is that these results can also be explained by global familiarity models of recognition memory. The only thing we need to assume is that in these studies some semantic features of the list items were stored in memory. This will result in a relatively strong match at test between the critical lure and the semantically related list items in memory. Hence, a higher false alarm rate is predicted for a critical lure belonging to a studied list than for a critical lure belonging to a nonstudied list. Another finding that has been explained by spreading activation is that false memory effects increase with the number of semantically related list items on the study list. Such effects are also predicted, however, by global familiarity accounts because the overall match between the critical lure and the list items will be stronger the more items on the study list are similar to the lure (see Arndt & Hirshman, 1998).

To conclude, the results of the present study show that global familiarity models provide a viable account of false recognition. The present paper is, of course, not the only one to mention the ability of global familiarity models to account for false recognition. In their original paper, Roediger and McDermott (1995) already discussed the ability of global familiarity models to account for false recognition effects. Moreover, some studies have been explicitly designed to test the predictions of global familiarity models (e.g., Arndt & Hirshman, 1998). Nevertheless, global familiarity models are often overlooked when explaining false recognition. The present study shows that global familiarity models should be taken into account when trying to explain false memories. In our view it would be interesting if future studies of the false memory effect would try to test the predictions of global familiarity accounts against those of alternative accounts such as spreading activation.

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