Associative Relatedness Enhances Recall and Produces False Memories in Immediate Serial Recall

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Abstract

The influence of permanent lexical network in immediate serial recall is well established. The corresponding influence of permanent semantic networks is less clear although such networks are known to both facilitate memory in long-term memory tasks and to produce false memories in those same tasks. The current experiment involves the study of Deese-Roediger-McDermott (DRM) lists for immediate serial recall. The trials in the experiment involved presenting the six strongest items from the DRM lists either in intact associatively related lists or where those items had been randomly mixed to produce unrelated lists. The results of the experiment indicated that the associatively related lists were better recalled in order than unrelated lists and the non-presented critical lure was falsely recalled relatively frequently. The results of the experiment confirm the importance of associative semantic networks in short-term memory.

Recent theorising about the role of short-term memory in broader facets of cognition has emphasised strong links with language. Speech-related phonological codes play a crucial role in short-term recall; the frequency with words are used in the language influences short- term recall; words are better recalled than unfamiliar non-words; and people with neurological damage who experience language difficulties often experience difficulties in short-term memory tasks. Consequently, there is widespread agreement that long-term lexical memory is a major influence upon what is recalled in short-term retention tasks both at the time of encoding (Jeffries, Frankish & Lambon Ralph, 2006; Romani, McAlpine & Martin, 2008) and at the time of recall (Hulme, Maughan & Brown, 1991; Schweickert, 1993). Moreover, there is growing evidence that the organisation of long-term lexical memory has an effect upon recall to the extent that pre-existing lexical networks influence the likelihood of recall (Goh & Pisoni, 2003; Roodenrys & Hinton, 2002; Roodenrys, Hulme, Lethbridge, Hinton, & Nimmo, 2002). Words with large interconnected phonological networks are better remembered than those with smaller networks (Chan, Vitevich & Roodenrys, 2009), which leads to the interesting proposition that non-presented items are none-the-less impacting upon the episodic recall of items on a serial recall task and that impact depends critically upon the number and strength of interitem associations.

Other researchers have extended the exploration of long-term memory effects by evaluating the impact of semantic attributes of the study material such as concreteness (Romani et al., 2008; Walker & Hulme, 1999) and by evaluating the effects the semantic relationship between items by manipulating taxonomic relatedness (Poirier & Saint-Aubin 1995; Saint-Aubin & Poirier, 1999). These studies again confirm that pre-existing semantic attributes and relationships are also influencing short-term recall. The current research extends the exploration of semantic contributions by examining the proposition first proposed by Stuart and Hulme (2000; see also Hulme, Stuart, Brown & Morin, 2003) (but not empirically tested by them) that in addition to the influences of item specific semantic attributes, there is an added impact due the relational organisation of semantic memory. The working assumption is that permanent semantic knowledge consists of a network of associatively connected items that is distinct from but connected to a lexical network. It is further assumed that items in that network can interact with each other in ways that can facilitate recall, inhibit recall or produce false memories and that these effects will be found in short-term recall.

Associations in memory have come to encompass virtually anything that assumes a set of linked concepts and as such a wide range of phenomena have been explained using then notion of associations (e.g. co-occurrence of words and concepts, taxonomic membership, various forms of similarity: semantic, orthographic, phonological). In addition if one limits the notion to pre-existing relationships among semantic representations, it is clear that many different types of semantic relationships exist. Moreover, the basic problem of distinguishing between associative links and feature overlap accounts of semantic memory effects remain problematic (Hutchinson, 2003; Lucas, 2000). Many of the above issues and distinctions are going to be ignored for the present because it is not at all clear that associative effects do influence short term recall. Thus, the term associative network here represents a relatively generic definition of the term: a set of localist nodes that are mentally linked together as a result of past experience. The degree of connectedness among such networks, as indicated via responses to free association and priming tasks, has been shown to have an impact upon many episodic and semantic memory tasks (Collins & Loftus, 1975; Nelson, McEvoy & Schrieber, 1998; Nelson & Zhang, 2000).

There is one distinction that is important. As indicated earlier, semantic relatedness in short-term has previously been studied in short-term recall by way of having all items in a list being members of the same taxonomic category. It has been argued that semantic relatedness (e.g membership of taxonomic categories) is not necessarily the same as associative relatedness. Thus *bee* and *fly* are likely to share many features along with other members of the insect kingdom, but *bee* is going to be associatively related to *honey* whereas most other member of the insect kingdom will not. In addition, while we know that having *bee* and *fly* and other insects in a list leads to better recall than when all items in a list are from different categories (Poirier & Saint-Aubin, 1995), we do not currently know whether having *bee* and *honey* and other associates of *bee* in the list are going to have an equivalent beneficial effect.

There are a number of models of short-term memory that do potentially predict the associative similarity effects although none of these models have tested such predictions as yet. Oberauer (2002) has posited a spreading activation model of STM and the current experiments are set within that framework although it is acknowledged that recent psycholinguistic models (R. C. Martin, Lesch &Bartha,1999; N. Martin & Gupta, 2004) would probably make equivalent predictions.

The basis of Oberauer's embedded-component model of working memory is the belief that STM is equivalent to the activated portion of LTM (Shiffrin, 1975; Cowan, 1999) such that the basis of all remembering is long-term memory. LTM is depicted in the model in the traditional Collins and Loftus (1975) fashion as a network of nodes in which the items are connected by associative links. Items are represented in terms of different baseline levels of activation, where baseline activation is a function of prior experience with the item (e.g. recency, frequency). Learning a list in a short-term memory experiment involves activating the long-term representations of the list items above baseline levels. However, because items are connected to other items in LTM, activation will spread from the list items to the associtates of those items. Thus in terms of activation studying a list of items for serial recall involves the activation of list items together with non-presented associates of those items.
Depending upon which items are being activated there is the potential for both the facilitation of recall and for interference from strong competitors.

In addition to the activated part of LTM, Oberauer posits two sub-components, a region of direct access and the focus of attention. The region of direct access is seen as a limited capacity region where a small number of items are activated and temporary episodic associations among these items are formed and maintained. As the name suggests, items in these region are immediately accessible without the need for retrieval. The focus of attention is a sub-component of the region of direct access and its capacity is seen to be one item, the item that is currently being attended to in completing task demands.

Oberauer (2002) tested this model using a short-term recognition procedure involving memory for two lists one designated the relevant list and one designated the irrelevant list. The interest lay in the extent to which items that had been relegated to the activated component of LTM (the irrelevant list) influenced memory performance for the items in the direct access region (relevant list) and whether any influence could be localised to either of the two sources of information that is thought to underpin recognition, namely familiarity and recollection. The data indicated that participants could rapidly remove the irrelevant material from the capacity limited region of working memory. However, while still activated that irrelevant material could exert an influence on memory performance by increasing familiarity leading to intrusion costs in RT. In addition, these costs seemed to increase in situations where recollection seemed to be exerting less of an effect. In short, items outside the limited capacity region were interfering with memory for the items in the limited capacity region.

While the embedded components model has not been applied to serial recall, nor to associative similarity effects, plausible expectations could be derived. Thus if one studied a list of associatively related items for serial recall, recurrent spreading activation among those items should lead to the maintenance of higher levels of activation than in the case of a list of unrelated items. If recall is in part activation based (as is assumed by many current computational models of ISR) then associatively related items should be better recalled than unrelated items.

However, with a list of associatively related items spreading activation should also spread to other non-presented items in the network thereby raising their activation levels above threshold level. Thus, spreading activation increases the possibility of interference from other non-presented but activated associates. The model also suggests that any increased interference is only likely to be observed where episodic information has deteriorated or been lost. Thus, the working hypotheses for the current research are that associatively related lists will be better recalled than unrelated lists and that the influence of non-studied items in the associative network will be observed particularly when episodic information is at its weakest.

While associative relatedness has not previously been studied in ISR, it has been widely explored in long-term recall and recognition studies and underpins the dominant account of false memory effects. In the Deese-Roediger-McDermott (DRM) false memory task, people study lists of associates of a never-presented lure. For example, they will study *thread pin eye sewing sharp point pricked thimble haystack pain hurt injection*, all associates of *needle*. When asked to recall or recognise items from the list there is a strong tendency for the participants to confidently produce the non-presented lure. Note too that among the studied items, there are different degrees of associations among the list item. Thus *thread* is not associated with *pin* and *sharp*, but *pin* and *sharp* are associated with each other. McEvoy, Nelson and Komatsu (1999) explored the associative network characteristics of the DRM materials that determined both false recall of the lure and correct recall of the list items. For false memories the prime determinant of recall was the associative strength from the list items to the lure. For veridical recall, the prime determinant was the density of the interconnections among the list words. The more associatively interconnected the list words the better the memory for those words. Thus in the long-term domain the DRM paradigm is useful for demonstrating both the facilitative and interference effects of associative similarity. The intent of the current paper is to use the DRM paradigm to explore similar effects in the short-term domain.

While there is substantial research involving the DRM paradigm in long-term settings, there are only two studies that have explored these false memory effects using short-term paradigms. Coane, McBride, Raulerson and Jordan (2007) have embedded the DRM lists within a STM recognition (Sternberg) task. With memory set sizes of three, five and seven they measured both accuracy and RT for recognition of list items, the non-presented critical lure and other non-related, non-presented items. There were two principle findings. Firstly, participants falsely identified the non-presented critical lure as being present on the list on at least 20% of trials. Secondly, the RTs for the critical lure were considerably slower that other types of probes when the critical lure was correctly rejected and when it was falsely endorsed as a list item. Coane et al. argue that their critical lure data can be explained if it is assumed that with spreading activation, the familiarity levels of the lure are raised and require more monitoring than unrelated items. This increased need for monitoring is reflected in increased processing time in order to correctly reject the item. Thus, at least part of Oberauer's model has been confirmed in that the intrusion costs emerge through the activation of a non-studied but key item in the associative network.

Atkins and Reulter-Lorenz (2008) also explored DRM false memories in the short-term domain. Their task involved memory for four-item lists of associates that were tested after four second retention interval filled with a math verification task. Free recall or recognition of the list items was required and the dependent measure was the frequency of different error types. With recognition non-presented lures were frequently falsely recognised and response times to these lures were relatively slow compared to other types of probes. In the free recall conditions, the lure was again frequently recalled, much more frequently that either phonological intrusions or other types of intrusions. Thus, in delayed short-term free recall of short lists there is evidence for associative relationships affecting memory performance.

In sum, both theoretical and empirical considerations lead to the possibility that pre- existing long-term semantic associative networks should have an influence upon short-term recall. If this is the case then two clear predictions emerge. Firstly, associatively related lists should be better recalled than unrelated lists, given that it is highly likely that associative connectivity will be greater in related lists than unrelated lists. Secondly, recall of false memories should be present in DRM lists given that all list items have backward associations to the critical lure.

To test these notions the current research deals with the immediate serial recall of lists in which the items in each list are either all associatively related to a non-presented critical lure (and are reasonably well associated with each other) or they are unrelated to each other. The use of serial recall is important for a number of reasons. Firstly, while serial recall requires both item and order memory, memory for the order of items is the dominant aspect of task performance. As such, it is quite possible that item memory effects may be weaker in an order memory tasks than item memory tasks like recognition and free recall. In addition it is likely that the speech based effects may dominate semantic effects on an immediate test (Tell, 1972; Tehan & Humphreys, 1995). Lastly, immediate serial recall has been the task of choice in developing theories of short-term memory and working memory. It is the task that is most closely associated with the links between short-term memory and long-term lexical effects and thus it is important to establish that other semantic/associative effects occur in this task as well.

Experiment 1

All the following experiments involve serial recall of DRM lists. Each trial involves the presentation of the six strongest associates of a non-presented lure. Performance on these trials was compared to performance where the six items were unrelated. It was expected that memory would be better on the associatively related lists and that recall of the non-presented lure would be a frequent source of error.

Method

Participants.

Forty introductory level psychology students participated in the experiment for partial course credit. Twenty participants were tested immediately after list presentation and half were tested after a two second filled delay.

Materials

The materials in this experiment were selected from the Stadler, Roediger and McDermott (1999) norms regarding word lists that create false memories. The 20 highest false memory producing lists from these norms were selected. These lists consist of the lure and then 15 associates of the lure. We chose the six items with the strongest backward associates of each lure to serve as the memory materials.

Participants studied a total of 20 six-word trials in the experiment; 10 trials where all six items were associatively related to a non-presented lure and 10 trials where the six words in the list were unrelated to each other. The first step in creating the lists was to randomly allocate lists to either related or unrelated condition. To create the associatively related trials, the six items in a list were assigned to the six serial positions in descending order of strength to the lure, that is strongest in the first serial position and the weakest in the sixth serial position (e.g. *bed rest awake tired dream wake*). To create the unrelated items, items were again assigned to serial position in terms of strength (all strongest associates were always in the first position and all weakest associates were in the sixth position, etc) but the items were randomly assigned to trials (e.g. *bed valley blaze tough temper point*). Thus each word always appeared in the same serial position within a list for each participant and what varied across participants and conditions was whether or not the other words in the list were related or not. The order of the 20 lists was randomised. Individual sets of trials for each participant were created using this procedure.

Procedure

Participants were told that they would be presented with lists of six words and that their task was to recall the words in order. They were instructed that should they forget a word they were to replace the forgotten word with the word "something" in order to preserve the order of the sequence.

The items were presented on a computer screen at the rate of one word per second. On an immediate test, the trial ended with a row of question marks at which point participants attempted to recall the words in order. On a delayed test, two two-digit numbers appeared on the screen, again at a rate of one number per second, and participants were required to read each digit pair aloud. The row of question marks followed the second number at which point participants again attempted to recall the items in order. For both immediate and delayed tests, participants had nine seconds to recall the words before the next trial commenced. The experimenter recorded participants' responses on a hard copy of the input.

Results

The essential findings reflected in Figure 1 are that related items were better recalled in position than unrelated items and this was true for both immediate and delayed recall. Secondly, as is evident in Table 1, the majority of errors were either omission or order errors, but on both immediate and delayed tests, there were many instances where the critical lure was falsely recalled.

Insert Figure 1 about here

Correct Recall: In exploring relatedness effects, it has become standard practice to report three measures of recall: the traditional measure of recalling the item in its correct position, an item recall measure where the item is considered correct if it has been recalled at all irrespective of what position it was recalled in, and an order accuracy measure where the probability that an item was recalled in its correct position given that an item has been recalled is calculated. Table 1 presents the effects of relatedness on these three measures collapsed across serial position.

Insert Table 1 about here

A 2 x 2 mixed design Anova, indicated that recall of related lists was better than unrelated lists for correct-in-position scoring, $F(1,38) = 52.42$, $MSE = .009$, $p <.000$, and for item scoring, $F(1,38) = 140.74$, $MSE = .005$, $p <.000$, but not for order accuracy, $F(1,38) = 1.49$, $MSE = .010$, $p =.23$. Recall was better on an immediate test than on a delayed test for all measures: Correct in position, $F(1,38) = 24.71$, $MSE = .038$, $p <.000$, item scoring, $F(1,38) = 33.85$, $MSE = .026$, $p <.000$, and order accuracy, $F(1,38) = 4.51$, $MSE = .059$, $p =.040$. None of the interactions were significant.

Lures: The frequency with which lures were recalled is presented in Table 2. An independent groups t-test confirmed that more lures were recalled on a delayed test than on an immediate test, $t(38) = 2.47$, $p = .018$

Insert Table 2 about here

Forty five percent of participants made at least one lure intrusion on an immediate test and seventy five percent of participants made at least one lure intrusion on a delayed test. In addition quite a substantial proportion of participants on the delayed test made multiple intrusions. In sum, Table 2 suggests that the intrusion of the lure is a widespread phenomenon.

It is also interesting where the lures and other extralist intrusions appeared in the output protocol. These intrusions can be scored in terms of the serial position in which they occurred or in relative terms. Since the pattern is very much the same for both measures, we report the intrusions in terms of the verbal output position. The groupings have been made in terms of first item output, second item output, output in the middle of the protocol (third or fourth item), output as the second last item, and output as the last item. As is evident in Table

3, the vast majority of the intrusions, both lures and extra-list intrusions, occur towards the end of attempts at recall, presumably when the quality of episodic information used to support serial order is less than optimal. With respect to the lures, there were two interesting errors. The first intrusions were due to the replacement of “mug” with cup and those in the middle were almost always due to “road” and “tough” being combined into “rough”.

Insert Table 3 about here

Discussion

The results of the current are quite simple. Items in associatively related lists are better recalled in serial order task than items in unrelated lists on both immediate and delayed conditions and this is true of all serial positions. This benefit is reflected in better item memory but not in order memory. In addition, associative false memories emerge in this short-term serial recall task as they do in short-term delayed free recall and in short-term recognition. The results at their most basic level clearly indicate that those items presented on the current trial interact with other items in permanent semantic memory that have not been presented. This finding is important because no current computational models of ISR account for the influence of pre-existing associative links between items nor do any of the models have mechanisms that produce false memories that are derived from semantic factors.

The item-order distinction is based upon the logic that correct serial recall involves the combination of two distinct pieces of episodic information: that an item appeared on the current trial and secondly, where that item appeared within a trial. Furthermore it is assumed that a correct-in-position score can be decomposed into its component parts. Thus, by scoring recall simply on the basis of what items were remembered, ignoring in what position they were recalled, it is argued that the measure taps into item memory. Thus, item memory involves retrieval of information about membership of the current trial. Order accuracy is typically measured by determining the extent to which an item has been recalled in its correct serial position given that the item has been recalled. This measure is seen to tap order memory and reflects more fine grained episodic information of the exact location of that item within a list. Given the assumption that spreading activation among a network of associates produces increased levels of activation, such supra-threshold activation would be indicative that the item has recently been encountered probably on the most recent trial. That is enhanced activation would result in better item memory. However, enhanced activation need not in and of itself provide any detailed information concerning the precise position an item occurred within a list (see Page & Norris, 1998, for an alternative view).

Item interactions of the type found in the current experiment are consistent with the assumptions of Oberauer’s (2002) general model of short-term/working memory in which the maintenance of serial order is not a central issue. Assuming that short-term recall is supported by activated components of associative LTM, spreading activation among that network provides a ready explanation for both the facilitative and interfering effects seen in the current data. Moreover, it predicts that non-studied items can exert a detrimental impact upon recall of presented items. The model also suggests that interference should be maximal when episodic information is at its weakest and the data again appear to be consistent with such assumptions in that the recall of the lure is occurring very late in the list.

The item interactions observed here are potentially handled by some of the psycholinguistic models of recall. These psycholinguistic models have been proposed to explain dissociations between patients who show phonological deficits in STM and other word processing tasks but no semantic deficits in the same tasks, and patients who show intact phonological processing, but show semantic deficits in these tasks. Similar deficits in short-term memory and word processing tasks means that in these models STM is very much linked with lexical processing, and long-term lexical and semantic memory. The models developed by R. C. Martin, Lesch and Bartha (1999) and N. Martin & Gupta (2004) are quite similar in that they are both connectionist models of semantic memory which are supported by input and output buffers. In both models long-term knowledge structures (phonological, lexical and semantic layers) are the primary drivers of memory and processing outcomes. The input buffer maintains information about serial order and the output buffer is required to for response preparation. Consequently, item and order memory are maintained in different layers in the system with order memory being maintained in the input buffer and item interactions occurring in the semantic memory layers. As is the case with most recurrent connectionist networks spreading activation across layers in the network makes both facilitation and interference possible. Thus activation among associatively related items is likely to produce both strengthening of list items and the strengthening of potential competitors. The fact that the locus of the facilitative effects is with item memory and not with order memory is consistent with the architectural assumptions of these models.

The finding of beneficial effects of associative relationships among items represents a second instance of semantic relationships having a facilitative effect on immediate serial recall. At a gross level, the current effects are very similar to those observed when lists of taxonomically related items are studied (Neale & Tehan, 2007; Poirier & Saint-Aubin, 1995; Saint-Aubin & Poirier, 1999). That is, when items on an immediate serial recall trial come from a single taxonomic category, there is a correct-in-position memory advantage compared to trials where the items on the list are all unrelated. As in the current experiment, the memory advantage for taxonomically related items is limited to item memory with no effect upon order memory. This suggests the interesting possibility that taxonomic similarity effects might well be explained in terms of spreading activation among category members (Saint- Aubin, Ouellette & Poirier, 2005). This possibility is largely ignored in current accounts of the taxonomic similarity effect which tend to treat semantic similarity effects as additional instantiations of the reconstruction hypothesis (Hulme et al. 1991). Thus, Poirier and Saint- Aubin (1995) explained their results by assuming LTM could be used to reconstruct a degraded phonological trace of the item. With lists of items from the same taxonomic category, category knowledge could be used to restrict the size of the search area in long-term memory leading to an increased likelihood that an item would be recovered (e.g. knowing that all the items on the list were reptiles could facilitate the reconstruction of a fragment like *cr_ _odi_ e*). Neale and Tehan (2007) argued that category membership was being used as a retrieval cue, as is the case in long-term tasks, and it was the use of this retrieval cue that was instrumental in producing the advantage in the similar lists. The key feature of these explanations is that there is no need to assume the existence of associative links between items for the cueing or search space explanation to be effective.

At the more fine grained level, the current results are potentially informative. Thus, there is no current empirical information concerning the types of intrusions that are made in taxonomically related lists. If associative and taxonomic lists are indicative of the same processes then one might predict that strong instances of a category could be relatively frequent sources of intrusions. Moreover, these intrusions should occur towards the end of the list.

To this point the argument has been based on a spreading activation view of semantic memory and has ignored alternative views of knowledge representation such as feature overlap and compound cue accounts. While there is insufficient data available in the current results to address this issue, the use of serial recall has the potential to at least discriminate between spreading activation and feature overlap accounts. Thus, one of the extremely robust benchmark findings in immediate serial recall is that high overlap among phonological features of list items (e.g. *man cad lap map lad can*) has detrimental effects on order memory. Current theoretical accounts of this phenomenon stress the shared features in the long-term phonological representations of these items. It is the case that when taxonomic similarity is manipulated the effects are not as robust as phonological similarity effects, however Saint-Aubin et al. (2005) have shown that with large numbers of participants, in their case in excess of 200 participants, the same detrimental effect of similarity upon order memory can be observed. They also note that with smaller sample sizes it is often the case that order memory for similar lists is impaired, although not significantly so, at the level of group means. These findings are again suggesting that members of taxonomic categories share common semantic features and as such the findings are consistent with a feature overlap account of semantic memory. Given similar phonological and taxonomic similarity decrements in order memory, it would seem that immediate serial recall is an excellent way of testing feature overlap accounts of semantic memory. However, the current results of marginally enhanced order memory at the group mean for associative related items are not consistent with the feature overlap account and are suggestive of a more complex situation. Clearly further exploration of associative and taxonomic effects in short-term order memory is warranted.

Recent developments in theorising about STM have demonstrated that episodic recall of a short list of items is influenced by the pre-existing lexical network of those items. The current results complement the language based effects by showing that item interactions among permanent associative networks also have an impact upon immediate serial recall. While the effects of associative network effects on short-term memory have been suggested previously in the literature (Hulme et al., 2003; Saint-Aubin et al, 2005; Stuart & Hulme, 2000) the current research is the first to test the notion that associative networks can have both facilitative effects upon recall and induce false recall at the same time. While these phenomena have been well established in the long-term literature for over 15 years it is somewhat surprising that they have largely been ignored in the short-term domain with the consequence that no existing computational models of immediate serial recall are able to handle either the facilitative effects or the false memories that are present in the current results. That associative relatedness and false memory effects can be observed just as readily in immediate serial recall adds further weight to the notion that both short-term and long-term recall are served by the same general memory principles and processes (Surprenant & Neath, 2009).

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Table1

Proportion correct recall (CIP, Item, Order) and errors as a function of associative relatedness and retention interval

	CIP	Item	Order	Om	Tran	Lure	Phon	Othr
Immediate								
Related	0.62 (.04)	0.70 (.03)	0.79 (.03)	0.18	0.17	0.06	0.00	0.02
Unrelated	0.47 (.04)	0.61 (.03)	0.76 (.04)	0.33	0.14	0.00	0.01	0.04
Delayed								
Related	0.41 (.15)	0.60 (.12)	0.67 (.18)	0.34	0.19	0.14	0.01	0.03
Unrelated	0.25 (.13)	0.39 (.12)	0.64 (.24)	0.54	0.14	0.00	0.01	0.03

Note: CIP = Correct in Position, Item = Item Scoring, Order = Order Accuracy, Omis = Omission Error, Tran = Transposition Error, Lure = Critical Lure Intrusion, Phon = Phonological Intrusion, Othr = Other errors.

Table 2.

Number of participants falsely recalling the "lure" as a function of the number of false memories produced and retention interval.

	Number of Lures recalled				
	0	1	2	3	4
Immediate	11	6	3		
Delay	5	7	5	1	2

Table 3

Frequency of intrusion recall as a function of output position, retention interval and type of intrusion.

		First	Second	Middle	Next to Last	Last
Immediate	Lures	2		2	3	5
	Extra-list		2		6	8
Delay	Lures	1	3	4	7	13
	Extra-list	3	3	2	3	16

Figure Caption

Figure 1. Proportion of items recalled in correct serial position as a function of associative relatedness and retention interval.