# Semantic Networks and Order Recall in Verbal Short-Term Memory

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**Abstract**

In a recent paper, Acheson, MacDonald, and Postle (2011) made an important but controversial suggestion: They hypothesised that a) semantic information has an effect on order information in short-term memory (STM) and b) that order recall in STM is based on the level of activation of items within the relevant long-term memory (LTM) network. However, verbal STM research typically has led to the conclusion that factors such as semantic category have a large effect on the number of correctly recalled items and little or no significant impact on order recall (Poirier & Saint-Aubin, 1995; Tse, 2009). Both of the studies reported here tested the hypotheses advanced by Acheson et al. Results show that as predicted, manipulating the putative activation of list items significantly impacts the recall of item order.

**Keywords:** Short-term memory; working memory; order recall; immediate memory; activated long-term memory.

## Short- and Long-term Memory

We are all familiar with the experience of reading material from an area known to us. Expressions, arguments and ideas are recognised; our previous knowledge significantly supports our grasp of the paper. In important ways, this example illustrates one of the most fundamental functions that memory performs: allowing the past to support and guide our present interactions with the world. This paper is about the interaction between semantic knowledge and the last few seconds of our most recent past – the content of short-term memory (STM).

Until relatively recently, little systematic consideration was given to how the lexical/semantic properties of verbal items affect performance in STM tasks. However, current work bears witness to the growing interest in this area, with research systematically exploring the relationship between language organisation in long-term memory (LTM) and verbal short-term recall (e.g. Acheson, MacDonald, & Postle, 2011; Hamilton & Martin, 2007;, R. C. Martin, 2006; Majerus, 2009; and Thorn & Page, 2009). Nevertheless, there has been little work on factors associated with semantic LTM. The study reported here aimed to test a hypothesis that suggests that semantic LTM plays an important role in immediate memory for order.

### The Role of LTM in Short-Term Recall:

The study of LTM contributions to verbal short-term recall has typically relied on a classic task: immediate serial recall. In this task, a small number of verbal items are presented — usually between 5 and 7—and participants must attempt to recall these items, in their order of appearance, immediately after list presentation. It is now well established that word frequency/familiarity has a positive influence on immediate serial recall, as does concreteness and lexicality (see Saint-Aubin & Poirier, 1999a for a review). This is also true at a sub-lexical level; when trying to remember non-words, items containing more familiar phonemic components are better recalled (Thorn & Frankish, 2005). Currently, it can be argued that there are two general classes of views that address these findings. The first are typically known as redintegration accounts while the second suggest that verbal STM relies more directly on long-term representations.

**Redintegration**. From this perspective immediate recall is a two-step process. It is first assumed that participants encode verbal material into phonological forms, as suggested by the well know articulatory loop / working memory model (e.g. Baddeley, 1986). In the absence of rehearsal, these representations are thought to rapidly become degraded either by decay or through interference. At the point of recall, a retrieval mechanism produces a phonological representation as a candidate for output. The memory trace may or may not be degraded (but see Roodenrys & Miller, 2008). If the trace is intact then recall will not be problematic. However, if the trace is degraded a second step is initiated. Long-term lexical/phonological information is accessed in an attempt to reconstruct the item (e.g. accessing knowledge of words to complete a fragmented trace, somewhat like filling in the gaps in cr_ _odi_e). This reconstruction process is often referred to as redintegration (Hulme, Maughan, & Brown 1991; Schweickert, 1993). It has been used to explain lexicality, word frequency, concreteness and imageability effects upon serial recall. However, recent ideas about the contribution of long-term representations to memory over the short-term have started to move away from dual process accounts (i.e. degradation of phonological short-term memory followed by redintegration). For example, Thorn, Frankish and Gathercole (2009), after reviewing their work on phonotactic and lexical frequency, conclude that long-term knowledge impacts immediate recall accuracy in two ways: by strengthening the representations that support performance and by influencing the reconstruction process.

**Psycholinguistic and LTM Network Models**. Over the past few decades, the redintegration hypothesis was the dominant view of LTM effects on short-term recall. Currently however, another class of models is becoming increasingly influential. Although the models in this group are more heterogeneous, they suggests that the LTM representations and the systems involved in language processing are more closely related to short-term recall than the redintegration hypothesis suggests (e.g. Acheson & MacDonald, 2009). In its typical form, the redintegration hypothesis restricts the influence of LTM representations to the retrieval stage of short-term recall. The psycholinguistic and LTM network models we refer to here propose that there is considerable overlap between STM tasks and language processing; hence the semantic, lexical, and sublexical networks that are widely thought to underlie language representations are viewed as supporting STM. In essence, these models are mostly moving away from the classic suggestion that verbal STM relies on a separate system. Rather, the premise is that processing linguistic information for recall involves the activation of the relevant long-term networks; in turn, the characteristics of these networks will influence performance.

Burgess and Hitch (2006), for example, offer a computational / network model of verbal STM where items are represented within lexical and phonological inter-connected networks. More recently, in order to explain the effects of a number of lexical and sub-lexical variables, Roodenrys (2009) proposed that an interactive network model was necessary where various levels of representation, including letter, phonemic, and lexical levels are activated and compete with each other. Other recent models explicitly include semantic levels of representation also. This group holds the computational model proposed by Gupta (2003, 2009), the conceptual models proposed Cowan (1999; Cowan & Chen, 2009) and Majerus (2009), the psycholinguistic models proposed by Martin & Gupta (2004) and R.C. Martin (2006) and from cognitive neuroscience, the proposal of Acheson, et al. (2011).

Choice amongst the models described above depends on a number of developments, one of which is a better understanding of how semantic memory influences STM performance. Assuming the latter models are appropriate, then semantic LTM should influence STM performance in predictable ways. As of yet however, there has been little detailed investigation of semantic LTM effects in short-term recall in healthy adults. Exceptions include the work on categorical similarity and the recent work of Acheson et al (2011).

**Categorical Similarity**. Poirier and Saint-Aubin (1995; Saint-Aubin & Poirier, 1999a; 1999b; Saint-Aubin, Ouellette, & Poirier, 2005) re-examined the widely held idea that similarity amongst list items in immediate serial recall had an adverse effect upon STM for *order* recall. While this finding is relatively consistent when phonological similarity is manipulated, Poirier and Saint-Aubin argued that this was not necessarily the case with semantic similarity. In their experiments, they explored semantic similarity effects for both item and order memory by using lists of items that were either from one semantic category or unrelated to each other. They found that categorical similarity was advantageous to item memory but had little effect upon order memory; in effect, across conditions, order errors were proportional to the number of items recalled. As there are more items recalled for categorised lists, there is a proportional increase in order errors. In explaining their results, they suggested that the taxonomic category could be used as an extra retrieval cue supporting recall.

However, assuming semantic LTM underpins STM performance suggests another explanation of the semantic category effect and generates further predictions. The latter relate to the associative links that exist between the members of a given semantic category.

**Associative Links and Co-occurrence**. Saint-Aubin et al (2005) suggested that increased access to same category items might depend on their long-term associative links (see also Hulme, Stuart, Brown, & Morin, 2003). Items from the same category tend to co-occur more frequently than items taken from different categories and this is thought to strengthen their associative links in memory (Deese, 1960; Stuart & Hulme, 2000). This is in line with many conceptualisations of lexical/semantic memory in other fields, which often depict semantic/lexical memory in terms of a network of associatively related items; activation in one part of the network can spread and influence recall of other items in the network. It seems plausible that activating multiple items in an associative network might produce high levels of activation and support recall.

A related idea was put forward by Acheson et al (2011) although coming from a somewhat different perspective. Importantly, their particular proposal led us to new, specific and testable predictions. A quote from their paper makes their view clearer (emphasis ours): “After initial encoding, lexical activation is determined by repeated interaction with semantic and phonological representation. ***Serial ordering errors occur when the relative activation levels of the lexical items change because of this interaction***. (…). If the maintenance of information in verbal WM is achieved by virtue of activation of language-production architecture, this leads to the prediction that disrupting semantic processing should influence the relative activation of lexical-level representations, thus influencing serial ordering." (Acheson et al., 2011, p. 46). Acheson et al. used a dual-task strategy; when the interference task involved semantic processing, more order errors were produced than with a spatial task. This effect disappeared with non-words, i.e. there was no disruption by the semantic dual task.

Another way of “disrupting” semantic processing is by using associates that are highly related with a target item within a list. This is the strategy we adopted in the first experiment reported here. On the face of it, the view above predicts that semantically related lists should lead to more order errors than control lists that have reduced levels of inter-item activation. There are multiple studies that suggest this is not the case – but there is controversy surrounding this point (see Saint-Aubin, et al., 2005). As mentioned earlier, order errors are proportional to item recall and semantically related lists produce better item recall.

To summarise, according to the hypothesis just reviewed (hereafter AN for Activated Network view) manipulating item activation levels within a list should influence serial ordering - or the information serial ordering is based upon (Acheson et al., 2011). Exp. 1 manipulated the level of activation of a target item to test the prediction that this would increase order errors for that item.

In Exp 1, lists of six visually presented items were used. Experimental lists contained a target item, presented in position 5 and the three first items were strong associates of the target. Control lists contained the same three associates in positions 1 to 3, but the item in position 5 was unrelated (see Table 1 for list examples).

Table 1: Sample experimental and control lists

| | | | | | |
|---|---|---|---|---|---|
| Experimental list examples | | | | | |
| officer | badge | siren | fence | police | tractor |
| band | record | concert | yellow | music | tourist |
| Control list examples | | | | | |
| officer | badge | siren | music | tourist | yellow |
| band | record | concert | tractor | fence | police |

For the experimental lists, it is expected that the first three items will activate the target ($5^{th}$ item) within LTM networks, making its representation seem more like that of earlier list items. Based on the AN view, the prediction is that the target fifth item will migrate more often than a non-target item in the same position. Although it is difficult to make specific predictions because of the numerous constraints on order recall (e.g, there is only one position to which the $5^{th}$ item can migrate in one direction and 4 in the other), one possibility is that the target word moves towards typically better recalled positions. The latter would provide stronger evidence in favour of models which include the prediction of a semantic memory effect on order recall.

# Experiment 1

## Method

**Participants.** A total of 40 adults took part (14 men, age range from 18 to 57, mean 27); they were offered a small financial incentive (£7) for participating.

**Materials.** The experiment comprised 32 lists, with 16 experimental and 16 control lists. We first generated a set of 16 lists where the first three items were strong associates of a target word, based on the University of South Florida norms (Nelson, McEvoy & Schreiber, 2004). These words, when used as cue words in a semantic association / production task, generate the target as a strong (early produced) associate. The target was placed in the $5^{th}$ position of each list, and the remaining positions (4 & 6) were filled with unrelated words. The same words were then used again to create a further set of 16 control lists, so each word was used twice within the experiment. Control lists had the same three associates in the first positions, in the same order. The last three words were a random selection from the filler words and from targets associated with other lists. The 32 lists thus created were then mixed to create 4 sets, with a different order of lists. This was done such that a given trio of related words was presented once in the first block of 16 lists and once in the second block of 16 lists. Also, each block of 16 lists contained 8 experimental and 8 control lists. Each participant was only presented with one set of 32 lists, with sets counterbalanced across participants. A bespoke computer program controlled stimulus presentation and response collection.

**Procedure**. Participants were tested individually, in sound-proofed cubicles, within a session lasting approximately 20 minutes. Following instructions they completed two practice trials. A fixation cross appeared in the centre of the screen, for two seconds, indicating that the first word was about to be presented. Words appeared sequentially on the screen, for one and a half seconds each, and were separated by a 500 msec blank. After the six words from a list had been presented, participants were to type them into response boxes, in the order in which they had appeared in the list, starting with the word presented first (the program stopped Ps from typing a response if the previous one was not entered – except for the first answer). They were not allowed to backtrack to correct a previous response. If they did not remember a word, they were asked to type the letter “b” and proceed to the following position.

## Results and Discussion

The hypothesis examined here related to the recall of the critical word and its control both appearing in the $5^{th}$ position of each list. The prediction from the AN view was that there would be more movement of the 5th item in the condition where the first three items presented were strong associates of said target. All analyses reported as significant were related to a $p$ value < 0.05.

Table 2 presents correct-in-position scores (i.e. to be scored correct, the item must be recalled in its presentation position) as well as the item recall score (i.e. item scored correct if it is recalled, irrespective of position). The table also presents means for the critical 5th item. As perusal of the table shows, overall performance is similar in both conditions; it appears item 5 was better recalled in the experimental condition if one ignores the position of recall. The latter points towards more migration of that item.

Table 2: Mean recall across positions and for position 5

| | All positions | Position 5 |
|---|---|---|
| | *Correct in position scores* | |
| **Control lists** | 0.71 | 0.58 |
| **Exp. lists** | 0.71 | 0.58 |
| | *Item recall scores* | |
| **Control lists** | 0.78 | 0.68 |
| **Exp. lists** | 0.79 | 0.75 |

As would be expected, there were no statistically reliable effect for the correct in position scores. With respect to item scores, paired sample T-tests showed no reliable difference for the overall means, but there was a significant difference for position 5 ($t(39)=2.5$).

Figures 1 shows the frequency with which the item studied in position 5 is actually recalled in another position – essentially error frequency per position, for the 5th item. As can be seen, the frequency with which the 5th word is recalled in an incorrect position appears higher for the Experimental condition than for the Control condition, particularly for positions 2 and 3. A 2 (condition) x 5 (error position) repeated measures ANOVA revealed that errors were significantly less frequent for the Control condition, $F(1, 39) = 12.63$, MSe = 0.56. There was also a significant effect of position, $F(4, 156)= 16.76$, MSe =0.85 and a significant interaction, F(4, 156=2.75, MSe= .52. Simple main effect tests showed that there were more migration errors in the Experimental condition for positions 2 and 3.

These findings support the prediction of the AN account: when the first three items in a list are strong associates of the 5th item, the latter tends to migrate more than a control item appearing in the same position. What is more, the target item migrated towards typically better recalled positions, as expected.

However, there is an alternative interpretation of this finding. It suggests that the 5th item is simply more frequently recalled grouped with the related items. Although the task instructions emphasised ordered recall, participants might have subjectively grouped the related items and this could have generated order errors. Essentially, the alternative hypothesis suggests that the results are an artefact of a study/recall strategy rather than an indication that semantic activation plays a role in order encoding and maintenance. Still another view is that observed effects are attributable to activation from associative links but the target item is not recalled very often in position 4 because of the knowledge of list structure that develops over the experiment (i.e. Ps notice that item 4 is never related to the first 3). The next study used lists that eliminate any advantage that grouping could involve, making the use of the strategy much less likely.

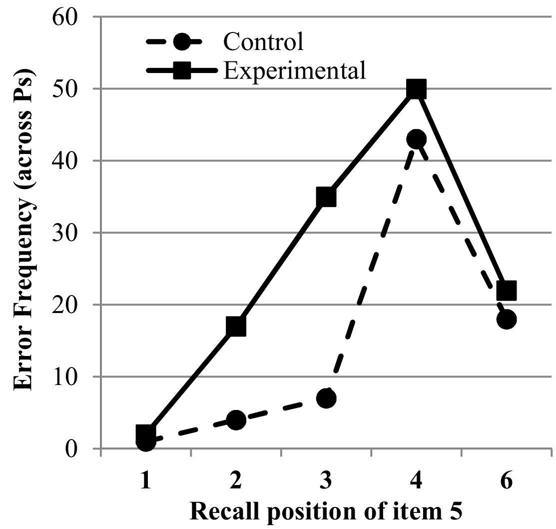

Figure 1. Errors for item 5 as a function of position.

## Experiment 2

This experiment was based on a re-analysis of the findings of a previously published study also calling upon immediate serial recall. The data was from Saint-Aubin et al. (2005). In their study, the experimental lists contained items that were all from the same semantic category (vegetables, sports, clothing, etc). As mentioned earlier, items from the same category co-occur more frequently in the language and as a result, have associative links. Based on the AN view, we would expect heightened co-activation for these lists, relative to control lists containing unrelated items. Importantly, one would not expect any special grouping strategy for the categorised lists as all the items are from the same category. The control lists were constructed by re-organising the items from the semantically related condition so that each word within a list was from a different semantic category. Each condition involved the same items overall; however, semantic category was manipulated between participants, with N=70 in each group. All lists were seven items long; there were 14 lists presented in each condition. The details of the methodology are otherwise similar to the study reported here and can be found in Saint-Aubin et al. (2005).

### Results and Discussion

As the lists used in this experiment were seven items long, we examined the recall of items 5, and 6. These seemed like the best candidates for two reasons: a) activation can be reasonably assumed to grow with the number of related preceding items, so we would expect it to be high for these later items and b) there needs to be a reasonable number of errors made for reliable migration analyses to be possible. In an immediate serial recall task, the highest performance is typically observed for the first few items; the last item (7) is of less interest as it can only migrate in one direction.

Figures 2a and 2b summarise the main findings. As can be seen, there were more migrations for the related items relative to the Control condition. The results for each position were analysed with two mixed ANOVAs; the between-subject factor was list type (categorised or not) and the within-subject factor was error position. For position 5, there was a main effect of list type, $F(1, 138)= 10.05$, $MSe= 0.516$, of position, $F(5, 290)= 82.0$, $MSe= 0.514$, as well as a significant interaction, $F(5, 690)= 4.45$, $MSe= 2.29$. The same effects were obtained for position 6, with list type $F(1, 138)= 24.69$, $MSe= 0.626$, error position $F(5, 290)= 86.81$, $MSe= 0.718$, and the interaction $F(5, 690)= 14.10$, $MSe= 0.718$ producing reliable effects. Simple main effect tests revealed the following: for the words studied in the 5$^{th}$ position, the difference between conditions was only significant for recall errors in position 4. For the items studied in the 6$^{th}$ position, this difference was significant for the errors observed in positions 4 and 5.

These findings fit nicely with those of Exp. 1; in both experiments, an increase in order errors / migrations for semantically related lists was observed, relative to control list, as predicted by the AN account.

## General Discussion

Previous interpretations have insisted that categorised lists have almost all of their effect by increasing item recall (irrespective of position; Saint-Aubin & Poirier, 1999a, 1999b). This increase is accompanied by a proportional increase in order errors. So, if order error proportions are the measure called upon, there is typically no effect of category on order. However, Saint-Aubin et al. (2005) did report a statistically reliable effect of categorised lists on the *proportion* of order errors.

The AN model discussed here offers a straightforward and parsimonious interpretation of this typical pattern of findings: the representation of the words in an immediate serial recall task relies on available language processing systems, including activation within and between phonological, sub-lexical, lexical, and semantic networks. Categorised lists lead to heightened network activation which produces better item retrieval as well as perturbation of the representation of item order.

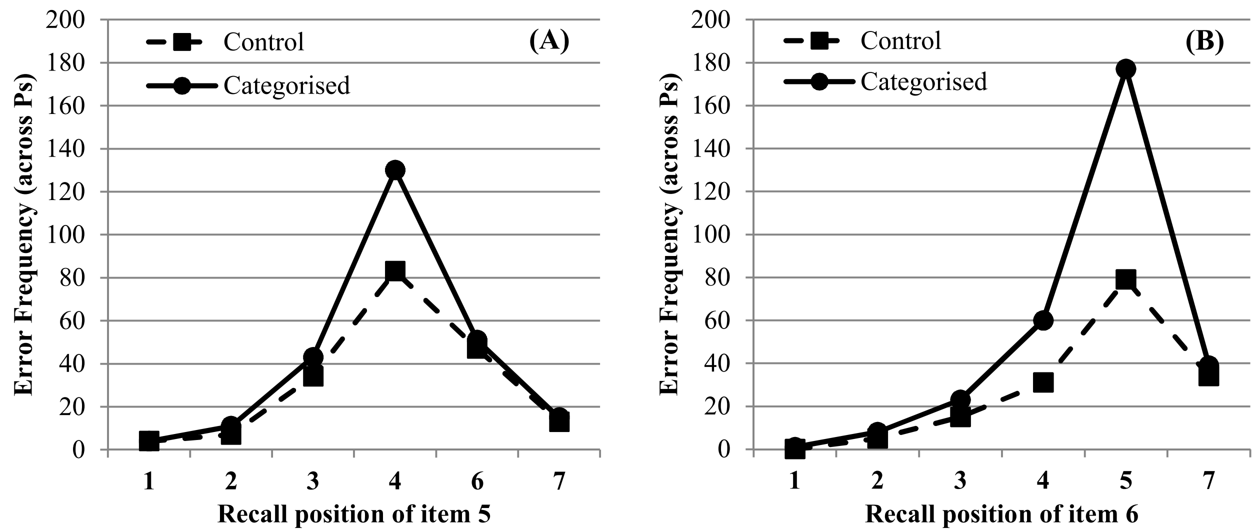


Figure 2. (A) Error frequency for item 5 and (B) item 6 as a function of recall position.

Our aim in this paper was to test a specific prediction derived from the Acheson et al (2011) proposal; the latter suggests that short-term memory relies on the LTM networks available for language processing. Our findings produced a pattern that was very much in line with the derived predictions. One could possibly interpret these findings posthoc within the redintegration framework perhaps by assuming that activation can perturb the order in which items are rehearsed. We would argue that our results are best interpreted within a model where STM relies on LTM representations and available LTM networks.

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