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Are Priming and Recency Effects Parts of the Same Implicit Memory Process?

by

Sergio Marini

A dissertation submitted to the Graduate Faculty in Psychology  
in partial fulfillment for the requirements for the degree of  
Doctor of Philosophy, The City University of New York

2001

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This manuscript has been read and accepted for the Graduate Faculty on Psychology in satisfaction of the dissertation requirement for the degree of Doctor in Philosophy.

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## Abstract

Are Priming and Recency Effects Parts of the Same Implicit Memory Process?

by

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Recency is the better recall of the last items in a serially presented list, and priming is the change in performance on a task, caused by the previous presentation of information, not requiring the participant's conscious awareness. Baddeley and Hitch (1993) argued that recency and priming may be the result of the same implicit memory process. Their hypothesis was supported by evidence that priming and recency do not dissociate with respect to several variables.

Questioning their conclusions we designed a study in which we expected to find dissociations. Presentation modality and stimulus frequency were chosen as independent variables, since previous studies suggested their differential effects on priming and recency.

In order to properly evaluate the Baddeley and Hitch (1993) hypothesis, we developed a unique paradigm that allowed a direct comparison of priming and recency. The new technique was not confounded, since the same presentation conditions were used before two tasks. After an identical presentation of the target list, composed of words and numbers, participants were either asked to recall as many words as they could from the

list, in order to assess recency, or to complete a stem completion task, in order to assess priming.

In Experiment 1 a suffix was presented at the end of the target list, while in Experiment 2 there was no suffix presented. In Experiment 3 the test was made more explicit by having participants focus their attention on the relevant stimuli. Measures of long term recall and long term priming were also obtained.

Dissociations were found in Experiments 1 and 2. In Experiment 1, priming was significantly greater than recency in the visual condition, while in the auditory condition there was no significant difference. In Experiment 2, priming was significantly greater than recency in the low frequency condition, while there was no significant difference in the high frequency condition. A number of other dissociations were also found.

The results contradict the hypothesis advanced by Baddeley and Hitch (1993). Thus, it is suggested that priming and recency should be regarded as resulting, at least in part, from different memory processes.

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## Table of Contents

	Page
Abstract.....	ii
Acknowledgments.....	v
Table of Contents.....	vi
List of Tables.....	ix
List of Figures.....	xi
I. General Introduction.....	1
1. Rationale of the Study .....	1
2. Memory and Cognition .....	2
3. Implicit and Explicit Memory.....	10
4. Recency .....	11
5. Priming .....	16
6. Modality Effects, Suffix Effects and Word Frequency.....	17
7.The Baddeley and Hitch Experiment.....	20
8.Background and Significance.....	23
II. EXPERIMENT 1: The Suffix Conditions .....	24
9. Method.....	27
10. Participants .....	27
11. Experimental Design.....	27

12. List Construction.....	30
13. Procedure.....	31
14. Descriptive Results.....	34
15. Method for Evaluating Priming and Recency.....	41
16. Log-Linear Analysis .....	45
17. Results and Discussion .....	47
III. EXPERIMENT 2: The Non-Suffix Conditions.....	63
18. Method.....	63
19. Participants.....	63
20. Experimental Design.....	64
21. List Construction.....	64
22. Procedure.....	64
23. Descriptive Results .....	64
24. Method for Evaluating Priming and Recency .....	71
25. Results and Discussion.....	74
26. Combined Analysis of Experiments 1 and 2.....	87
IV. EXPERIMENT 3.....	111
27. Method.....	111
28. Participants.....	112
29. Experimental Design.....	112
30. Procedure.....	112

31. Results and Discussion.....	112
32. Analysis of Experiments 2 and 3.....	120
33. Results and Discussion.....	120
V. ADDITIONAL RESULTS.....	133
34. Immediate and Delayed Recall of the Target List.....	133
35. Delayed Recall and Delayed Stem Completion of the Target List.....	142
36. Recall of the First Six Lists.....	152
37. Stem Completion of the First Six Lists.....	154
VI. GENERAL DISCUSSION.....	156
38. Appendix.....	169
39. References.....	171

List of Tables

Table	Page
1. Conditions in Experiment 1 .....	30
2. Observed Frequencies For the Log-Linear analysis of Experiment 1 .....	49
3. Result of the Logit Model Analysis for Experiment 1 .....	52
3a. Results of Fisher Exact Tests Performed Between the High and the Low Frequency Conditions of Experiment 1 .....	56
3b. Results of Fisher Exact Tests Performed Between the Auditory and the Visual Conditions of Experiment 1 .....	57
3c. Results of Fisher Exact Tests Performed Between the Priming and Recency Conditions of Experiment 1 .....	58
3d. Results of Fisher Exact Tests Performed Between the Priming and Recency Conditions in the Two Presentation Modalities in Experiment 1 .....	61
4. Observed Frequencies For the Log-Linear Analysis of Experiment 2 .....	73
4a. Result of the Logit Model Analysis for Experiment 2 .....	75
4b. Results of Fisher Exact Tests Performed Between the High and the Low Frequency Conditions of Experiment 2 .....	79
4c. Results of Fisher Exact Tests Performed Between the Auditory and the Visual Conditions of Experiment 2 .....	80
4d. Results of Fisher Exact Tests Performed Between the Priming and Recency Conditions of Experiment 2 .....	81
4e. Results of Fisher Exact Tests Performed Between the Priming and Recency in the High and Low Frequency Conditions of Experiment 2 .....	84
5. Observed Frequencies For the Log-Linear Analysis of Experiments 1 and 2 .....	93

5a.	Result of the Log-Linear Analysis of Experiments 1 and 2 .....	94
5b.	Results of Fisher Exact Tests Performed Between the High and the Low Frequency Conditions of Experiments 1 and 2 .....	98
5c.	Results of Fisher Exact Tests Performed Between the Auditory and the Visual Conditions of Experiments 1 and 2 .....	99
5d.	Results of Fisher Exact Tests Performed Between the Priming and Recency Conditions of Experiments 1 and 2 .....	100
5e.	Results of Fisher Exact Tests Performed on the Data From the Interaction Task X Frequency of Experiments 1 and 2 .....	103
5f.	Results of Fisher Exact Tests Performed on the Data From the Interaction Modality X Suffix of Experiments 1 and 2 .....	104
5g.	Results of Fisher Exact Tests Performed Between the Auditory and Visual Conditions for the Interaction of Task X Modality X Suffix of Experiments 1 and 2 .....	108
5h.	Results of Fisher Exact Tests Performed Between the Priming and Recency Conditions for the Interaction of Task X Modality X Suffix of Experiments 1 and 2 .....	109
6.	Results of a Tukey hsd Test on the Comparison Between Experiments 2 and 3 .....	148
6a.	Results of Fisher Exact Tests Performed Between the Priming and Recency Conditions of Experiments 2 and 3 .....	131
7.	Results of the ANOVA on Delayed Recall and Delayed Priming of the Target list .....	144

List of Figures

Figure	Page
1a. Recall and Priming Results from the High Frequency Conditions in Experiment 1 .....	36
1b. Composite Results from the High Frequency Conditions in Experiment 1 .....	37
1c. Recall and Priming Results from the Low Frequency Conditions in Experiment 1 .....	40
1d. Composite Results from the Low Frequency Conditions in Experiment 1 (All Serial Positions).....	41
1e. Priming and Recency in Experiment 1 ( The Suffix Conditions).....	45
2. Experiment 1: Interaction of Task by Modality.....	60
3a. Results from the High Frequency Conditions in Experiment 2 .....	67
3b. Results from the High Frequency Conditions in Experiment 2 .....	68
3c. Results from the Low Frequency Conditions in Experiment 2 .....	69
3d. Results from the Low Frequency Conditions in Experiment 2 .....	70
4. Priming and Recency in Experiment 2 (Non-Suffix Conditions).....	72
4a. Interaction of Task by Frequency in Experiment 2 .....	83
5. Priming and Recency in Experiments 1 and 2 .....	88
5a. Interaction of Task X Modality X Suffix In the Suffix and Non-suffix Conditions.....	107
6. Results from the Low Frequency, Visual Conditions in Experiment 3.....	114
7. Results from the Distractor Lists in Experiment 3 .....	117
8a. Main Effect of List in Experiment 3 .....	118

8b.	Main Effect of Position in Experiment 3 .....	119
9a.	Stem Completion of Target Words in Experiments 2 and 3 .....	121
9b.	Recall of Target Words in Experiments 2 and 3 .....	123
9c.	Number of Target Words Recalled and Used in Stem Completion .....	125
9d.	Number of Participants Showing Priming and Recency in Experiments 2 and 3 .....	129
10a.	Interaction of Task X Position in Immediate and Delayed Recall .....	135
10b.	Interaction of Modality by Position in the Immediate and Delayed Recall Condition .....	137
10c.	Main Effect of Modality in the Immediate and Delayed Recall Condition .....	138
10d.	Main Effect of Position in the Immediate and Delayed Recall Condition .....	139
10e.	Interaction of Task X Frequency X Position in the Immediate and Delayed Recall Conditions .....	141
11a.	Interaction of Task by Frequency for Delayed Recall and Delayed Priming .....	145
11b.	Interaction of Task by Suffix by Modality for the Delayed Recall and Delayed Stem Completion Conditions .....	147
11c.	Interaction of Modality by Position for the Delayed Recall and Delayed Stem Completion Conditions .....	149
11d.	Main Effect of Serial Position in the Delayed Recall and Delayed Stem Completion Conditions .....	151

## Are Priming and Recency Effects Parts of the Same Implicit Memory Process?

Priming and recency have been, for the most part, elements of different aspects of memory research. References to priming effects have been more prevalent in research and theories of implicit memory, while the study of recency effects have been done primarily using explicit memory paradigms. Baddeley and Hitch (1993), argued that priming and recency may be the result of the same implicit memory residue. However, Baddeley and Hitch did not provide empirical evidence in support of their hypothesis, and only reported a number of other studies, where priming and recency were not directly compared. There is no direct evidence, in the literature that we know of, that clarifies the relationship between priming and recency. We decided to fill the gap in the literature by devising a new paradigm in which priming and recency could be analyzed under the same conditions.

Seven lists, composed of words and digits, were presented to participants. After the first six lists the participants were asked to recall the digits from that list. After the seventh list, half of the participants were asked to recall the words from that list, in order to assess recency, and half of the participants were asked to complete a stem completion list, in order to assess priming. This new paradigm then provides measures of recency and priming that resulted from identical conditions, allowing a direct comparison of the two effects.

In order to find possible dissociations between priming and recency, the two effects had to be measured under a number of different conditions. These conditions were chosen because they appeared to have different effects on priming and recency. Auditory

and a visual presentation conditions were used because the modality effect is a well documented contributor to recency (see Baddeley, 1990), with auditory presentation leading to greater recency than visual presentation. On the other hand, Roediger and Blaxton (1987) provided evidence of an implicit memory advantage when the modality of presentation and test was the same, so that performance on a visual stem completion task would benefit from visual presentation of the stimuli. The second condition selected was the frequency of the words used as stimuli. There is evidence of a low frequency advantage in stem completion priming tasks (Kinoshita, 1995), while explicit memory tasks do not appear to be affected by the frequency of the stimuli (Rajaram and Neely (1992). In all the conditions of Experiment 1, a suffix was presented at the end of the seventh list, while in all the conditions in Experiment 2, there was no suffix. The suffix conditions were chosen because the presentation of a suffix is known to diminish recency (Baddeley, 1990), while it was not expected to have any effect on priming.

If priming and recency were affected differently by the different conditions mentioned above, it could be argued that they may be parts of different processes. If the different conditions had the same effect on priming and recency, it would be evidence that they may be parts of the same memory process.

## MEMORY AND COGNITION

Cognition, broadly defined, is mental activity that includes the acquisition, storage, transformation, and use of knowledge. There are two important aspects to be added to the definition above. The first aspect is that mental processes do not necessarily require

conscious awareness, and the second is that these processes can occur very rapidly, but at the same time can be very complex.

One predominant metatheory used in the study of memory and cognition has been the information processing approach. According to the information processing approach, cognition can be defined as “the coordinated operations of active mental processes within a multicomponential memory system” (Ashcraft, 1994). By analyzing this general definition, we can see how the memory system is assumed to be composed of several elements. Furthermore, within these elements there are active mental processes being performed, and the operation of these processes appear to be coordinated across the different elements.

Probably, the best known early model of memory, based on the information processing approach is the Atkinson and Shiffrin model of 1968, also known as the Modal Model. This model suggests that there are three memory components. These components are sensory memory, short term memory (STM), and long term memory (LTM). In this model, sensory memory is seen as an input buffer device, where the information is encoded. There are a number of sensory modalities (e.g., taste, pressure, warmth), but the ones that have been studied the most frequently are the visual and the auditory modalities, which we will study here.

According to the Atkinson and Shiffrin model, information is transferred from sensory memory into STM. This component of memory is defined as “the memory buffer that holds current and recently attended information”(Ashcraft, 1994). STM is thought to

encode information from both sensory and long term memory. When in short term memory, the information is believed to be available for conscious and deliberate processing.

Finally, according to the model, the last component of the hypothesized memory system is long term memory, which is defined as "the memory system responsible for storing information on a relatively permanent basis"(Ashcraft, 1994). It is theorized that information is transferred to LTM via rehearsal. Rehearsal can be simple, that is rudimentary rote repetition of the information, or more complex, that is an active elaboration of the information into a representation of it, that may be more properly stored. Elaborative rehearsal is thought to lead to better retention than simple rehearsal.

One of the major early criticisms of the Atkinson and Shiffrin model has been over the need for a differentiation between STM and LTM. As a rule, simpler models are preferable to more complex ones, and therefore a model able to explain experimental evidence using two components should be preferable to a model using three.

Kintsch and Buschke (1969), tried to determine if experimental data would support a model where STM and LTM function as a single unit, or a model where the two systems are separate. They asked subjects to learn 16 English words in order. They argued that, if the Atkinson and Shiffrin model was correct, in immediate recall, the words in the beginning of the list should be in LTM, while if words were at the end of the list they should be in STM. Furthermore, it was argued that if the material in STM is stored in terms of the acoustic characteristics, and the material in LTM is stored in terms of

semantic characteristics, then the words at the beginning and the words at the end of the list should differ in regard to the type of material that interferes most with it. In fact, it was found that lists of words having semantic similarity produced more confusion errors in the beginning of the list, while lists of words having acoustic similarity produced more confusion errors at the end of the list. Thus, these researchers interpreted these results to support the Atkinson and Shiffrin distinction between STM and LTM.

Further evidence in favor of the modal model distinction between STM and LTM is derived from the field of neuroscience. Milner (1966), reported on the case of H.M., a patient who suffered from serious epilepsy. In order to diminish the intensity of the epileptic episodes, a portion of H.M.'s medial temporal lobes and hippocampus were removed. After the surgery, H.M. had an intact memory for events that took place before the operation, and his STM was also normal. However, he could not learn or retain new information over a long period of time. This evidence suggested that even with STM being normal, there was an inability to transfer information to LTM, again supporting the idea of a separation between STM and LTM, as stated in the modal model.

A number of studies still support the STM-LTM distinction, and a number of theories still separate the two, but overall the modal model appears to be too simple, and not able to fully explain all the experimental evidence available today. For example, both within STM and LTM there appear to be a number of different processes taking place.

While the Atkinson and Shiffrin model focused on the length of time the information has been in memory, a different kind of model, first proposed by Tulving

(1972), focused on the nature of the material stored in memory. Tulving's original model distinguished between two kinds of memory, known as episodic and semantic. Later a new category was added, called procedural memory. These three subsystems, Tulving argued, were all different components of what the modal model called LTM. However, Tulving suggested that STM is a different system, making his model somewhat still compatible with the modal model.

Episodic memory is thought to store information about personal experiences, including information about when an event happened, as well as the relationship between different events. An example of this type of memory would be someone's memory that the night before they had dinner after taking a walk in the park. According to Tulving, semantic memory is the organized knowledge we have about the world. It includes knowledge about the meaning of words and their relationship, and the knowledge about general facts about the world. For example, the knowledge that there are four seasons in a year would be an example of this general knowledge that is part of semantic memory. Finally, procedural memory involves the knowledge of how to do something. An example is the ability one has to ride a bicycle, or to click the mouse on a computer. Tulving (1989) provided evidence in support to his model. In one experiment, he asked subjects to perform a variety of semantic retrieval tasks. For example, he asked them to recall what they knew about the history of astronomy. PET scans of the subjects while performing these tasks revealed that the greatest brain activity occurred in the back part of the cerebral cortex. When the same participants were asked to perform a variety of episodic

retrieval tasks in which they were asked to recall a number of personal experiences, such as what they had done the previous weekend, PET scans showed that the greatest activity occurred in the frontal lobe of the cerebral cortex. Thus, his argument was that since performing semantic or episodic tasks led to activity in different areas of the brain, it was likely that the memory systems involved were also different.

Despite the evidence provided above, recent reviews of Tulving's model have been skeptical about the semantic/episodic distinction, and even Tulving himself has suggested that episodic memory may be an important kind of semantic memory, rather than a different system. There has been more agreement that procedural knowledge is a separate system.

Tulving and his colleagues tried to make his model more complete by adding a number of different systems to it, (Tulving and Schacter, 1990). These researchers argued for the existence of another category of memory which is different from any described above, which has been known as priming. They have argued that priming may be part of a specific type of memory, known as the perceptual representation system (PRS), which exists separately but closely interacts with other memory systems. Further experimental evidence led Schacter (1994) to theorize that the PRS may be composed of three subsystems, having different functions, called the auditory word form, the visual word form, and structural description. Thus the original model by Tulving has been revised, and a number of different systems have been added to it, in order to fit experimental evidence. This has led to the criticism that, as new experimental evidence emerges, and contradicts

the model, the proponents of the model add more complex pieces in an attempt to salvage it.

A different kind of approach to the study of memory is the level of processing approach (LOP). According to this approach, meaningful kinds of information processing lead to more permanent retention than shallow, sensory types of processing. For example, this approach would predict that more words may be recalled after judging the words' meaning, rather than their physical appearance. The LOP approach was first proposed by Craik and Lockhart (1972). The main difference between the modal model and LOP is that the latter is not an all encompassing theory, but it is a framework for thinking about memory as a process of analyzing stimuli. LOP proposes that individuals can analyze stimuli at a number of different levels. If a stimulus is analyzed at a shallow level, then the memory trace for it will be fragile, while if a stimulus is analyzed at a deep level then its memory trace will be more durable.

In support of the LOP approach, Craik and Tulving (1975) asked subjects to answer questions either about the meaning or about the physical appearance of words presented. When the questions were about the meaning of the words presented, the subjects were three times more likely to recall them than if the questions were about the appearance of the words.

The original LOP model did not mention retrieval, but only encoding. Later work suggested that individuals may be able to recall more material if the retrieval condition matches the encoding condition. For example, Bransford et al. (1979), found that when

subjects encoded information while focusing on the sound of the words presented, they could perform better than subjects encoding the meaning of the same words, if the final task was to determine if any of the words presented rhymed with a particular sound. In other words, shallow processing can sometimes be more effective than deep processing if the retrieval task emphasizes superficial information.

Currently Roediger (1990), is one of the major supporters of the LOP approach. In order to accommodate the findings described above, he developed the idea of transfer appropriate processing. According to this concept remembering is determined by the degree of similarity between the processing task and the test. More specifically, Roediger argued that both encoding and retrieval occur along a continuum between data driven (shallow), and concept driven (deep) processing. The closer encoding and retrieval fall along the continuum, the greater the performance during testing will be.

Even though the LOP approach appears to be promising both for its simplicity and its ability to explain a number of phenomena, there is a basic and major problem with it. The problem lies in the fact that there is no independent assessment of depth of processing. In general, if processing is deep, the model argues, retention will be better. If retention is then found to be better, the model argues that processing must have been deep. It is clear that this argument is not a valid one because of its circularity.

Thus, even though a number of memory models have been proposed, there is no single model that appears to be problem free, or to be able to explain all the experimental findings.

## IMPLICIT AND EXPLICIT MEMORY

Most of the current theories of memory make a distinction between explicit (also called declarative or direct) memory, and implicit (also called non-declarative or indirect) memory. Other researchers make a similar categorization, but refer to the two types of memory as memory with awareness and memory without awareness. Explicit, declarative, direct, or memory with awareness, may be defined as conscious or intentional recollection of prior events or experiences, which is typically assessed by tests of recall or recognition. On the other hand implicit, non-declarative, indirect, or memory without awareness, may be defined as the change in behavior or performance produced by prior experiences frequently assessed with tests that do not require any conscious or intentional recollection of the experiences. We will use the terms explicit and implicit memory to refer to these concepts.

There is a divergence of opinion regarding the cause of the implicit-explicit dichotomy. Some researchers, including Tulving and Schacter (1990), as well as Squire (1992), argue in favor of a system approach, in which neurologically distinct systems are responsible for different types of memory. According to this approach, explicit memory can be further divided into memory for facts and memory for events, also known as the semantic-episodic distinction. In addition, implicit memory can be subdivided into a number of subsystems that include motor skill learning, simple classical conditioning, sensory adaptation effects, and priming.

Other researchers, including Roediger and Blaxton (1987), argue in favor of a process approach. This approach to the explanation of the explicit-implicit dichotomy suggests that different tasks require different processes, namely that any particular task falls along a continuum of processes that are concept driven at one extreme, and processes that are data driven at the other. If the particular task evokes processing which is mostly concept driven, the type of memory most likely to be involved would be explicit. Conversely if the task evokes processing that is mostly data driven, the type of memory most likely to be involved would be implicit. Thus according to the process approach, there are no separate systems for the different types of memory, but the characteristics of the particular task are the determinants of the type of memory that would be used, along the explicit-implicit continuum.

## RECENCY

Recency may be defined as the better recall of the last item as compared with the middle items, in a list of serially presented items. One of the early theories that explained the recency effect was that of Waugh and Norman (1965), who proposed that the existence of two stores in memory was the cause of recency. They argued that a more permanent long term memory store was responsible for the recall of earlier items in a list, while another short term store was responsible for the recall of the last few items.

However, the most influential theory which attempted to explain recency, as well as other effects such as the modality effect and the suffix effect, was the Precategorical Acoustic Store (PAS) theory of Crowder and Morton (1969). The PAS theory suggested

that auditory sensory traces last a relatively long period of time, while visual sensory traces last for a short period of time. In addition, the sensory traces were thought to be responsible for the recall of the last portion of a list. By arguing that the participants had extra information in the auditory as compared to the visual memory trace, Crowder and Morton were able to explain the fact that recall in general, and in particular recall for the last portion of a list, is greater for auditory rather than visually presented lists of items, a phenomenon known as the modality effect.

In order to test their hypothesis Crowder and Morton (1969), presented sequences of nine digits using three different experimental conditions. In the Silent Vocalization Condition, participants read the stimuli silently, in the Active Vocalization Condition participants read the digits out loud, and in the Passive Vocalization Condition, participants viewed the stimuli and at the same time heard a tape of the stimuli being read. Performance for the last item in the lists was almost perfect for the Active and Passive Vocalization Conditions, while for the Silent Vocalization Condition, performance on the last item was about 50%. These results supported the idea that auditory information about stimuli, both active and passive, lead to greater recency than visual information.

Crowder and Morton (1969), also argued that the PAS had limited capacity, and the auditory information in it was constantly replaced by new information. Evidence supporting this idea came from research by Rundus (1971), in which a list of 20 nouns was presented to participants, who were instructed to rehearse them out loud. Even though the last items in the list were rehearsed less often than the items in the middle of the list, recall

for the items at the end of the list was much better. This recency effect could be explained by arguing that the last items in the list were still in a short term store at the time of recall.

The PAS theory was soon challenged. Evidence suggested that large recency effects could be found in modalities other than auditory. For example Manning and Gmuer (1985) found recency in an experiment where stimuli were presented visually, while Manning (1980), found some recency using tactile presentation. In addition, Campbell and Dodd (1980), using lipread stimuli, obtained a recency effect similar to the one obtained with auditory stimuli.

Another influential early explanation of recency was proposed by Glanzer (1972), who argued for a short term store able to hold about three items or chunks. Glanzer suggested that in a standard free recall paradigm, the last few items of the list may still be in such a short term store and therefore could be more easily retrieved, producing the recency effect.

Baddeley and Hitch (1993), however, were able to reject the theories that tried to explain recency as a short term memory phenomenon, using three types of evidence. The first is that recency can be found not only in short term memory, but also in long term memory. Long term recency has been studied mainly by using the continuous distractor paradigm. This technique consists of the presentation of a list of words, with each word separated by a distractor activity such as counting backwards, which also fills the gap between the last word presented and recall. Using the continuous distractor paradigm Bjork and Whitten (1974), as well as many other researchers, were able to obtain recency

effects that would have been canceled by the distractor activity between the last word presented and recall, if recency was a phenomenon confined to STM.

A second problem for the primary memory view of recency comes from a study by Watkins and Peynircioglu (1983). Using words from three different categories, they were able to obtain three simultaneous recency effects, one for each category.

The third type of evidence that goes against the short term memory explanation of recency comes from two studies by Baddeley and Hitch (1977), in which participants were required to perform a digit span task, while at the same time they performed a free recall task of a list of words. Since the digit span is also assumed to rely upon limited capacity primary memory then, if the primary memory hypothesis of recency was true, some interference in the amount of the recency effect in the free recall of the words should be expected. However, Baddeley and Hitch found that the recency effect was unaffected by the simultaneous digit span task.

Baddeley and Hitch (1993) argued that both long and short term recency can be explained by a simple ordinal or temporal discrimination hypothesis. The main point of this hypothesis can be best described in an analogy made by Crowder (1976), in which free recall of a list of stimuli is seen as analogous to looking back at telegraph poles on a railroad. The poles that are near are more easily discriminable, while as the poles become more distant it becomes harder to discriminate between them. Similarly, as an explanation for long term recency, as one moves away from the closest pole, the relation between

discriminability and distance will remain the same, that is, the closest pole will still be the most discriminable, and the farthest pole will still be the least discriminable.

An additional problem for the short term memory explanation of recency comes from the results of a study conducted by Gardiner and Gregg (1979). The researchers instructed participants in the visual condition to read stimuli out loud that were presented on a screen. Participants were further instructed to count backwards for 10-20 seconds, before and after each stimulus, including the last one. The recency effect, that should have been eliminated by the distractor activity after the presentation of the last stimulus was still present, creating a problem for the short term memory explanation of recency.

Surprenant et al. (1993), in a series of experiments involving immediate serial recall, examined the effects of discriminability and familiarity on recency. It was found that, even though both discriminability and familiarity had an effect on the overall level of recall, these manipulations had no effect on recency. The experimenters concluded that convincing recency occurred when the stimulus was a clear speech sound, and did not occur when the stimulus was degraded.

There is very little data on the occurrence of recency in implicit tasks. However, the small amount of information on the subject suggests that the recency effect does occur in implicit tasks. For example McKenzie and Humphreys (1991), performed a series of experiments in which two successive lists of words were presented to participants in an incidental mode. Participants were asked to classify the words in the lists. Then, at different delays, they were presented with a word stem completion task. If the participants

were in the implicit condition, they were asked to complete the stem with the first word that they could think of, while if they were in the explicit condition they were asked to complete the stem using one of the words previously presented in the two lists. The stems could be completed with either one of the words presented in the first list or one of the words presented in the second list. McKenzie and Humphreys argued that they could obtain a measure of recency by looking at the difference in the proportions of words taken from the first as compared to the second list. In the implicit task, at shorter delays, the proportion of words taken from the second list was greater, suggesting that the recency effect can occur in implicit tasks.

#### PRIMING

Implicit memory has been of particular interest in the field of memory in the last several years. This term was introduced in 1985 by Graf and Schacter in order to differentiate between explicit memory tasks, in which the participants are asked to recall a past experience such as the presentation of a list, and implicit memory tasks, where the participants are not asked to recollect a specific past experience but in which a recent past experience may influence performance. Some of the work in implicit memory focused its attention on the phenomenon of direct, or repetition priming. Such a phenomenon refers to the facilitation in the processing of a stimulus as a result of recent exposure to that stimulus. Priming has been observed in a variety of tests that do not make any reference to events that occurred earlier. One frequently used technique to test priming has been word stem completion. In a word stem completion task, participants are given the first few

letters of a word and asked to complete it by making it into a word, using the first word that comes to mind. Priming occurs when the probability of using a particular word is increased by its previous presentation in an unrelated task. It is thought that the participant is not aware of any relationship between the previously presented word and the word used in the stem completion task (Bowers & Schacter, 1990).

#### MODALITY EFFECTS, SUFFIX EFFECTS, AND WORD FREQUENCY.

A variety of experiments have shown that auditory presentation of verbal information leads to better retention than visual presentation. This phenomenon has been called the modality effect, and is especially evident for the last portion of the list of presented items. As described earlier, Crowder and Morton (1969), demonstrated that active and passive vocalization conditions lead to almost perfect recall of the last few items in a list, while for the silent vocalization condition performance on the same items was about 50%. Thus the modality effect appears to be present when information is presented acoustically, independently of whether the vocalization is active or passive. Furthermore, the modality effect seems to be closely tied to the recency effect because the advantage of the auditory over the visual presentation appears to be more evident at the end of the list.

The presentation of a not-to-be recalled item, a suffix, at the end of a list of items to be remembered has the effect of reducing the amount of recency produced by auditory presentation. Crowder and Morton (1969) did extensive work on this effect, which is

known as the suffix effect. The two researchers showed that sounds, like a buzzer or a tone, that are not speech based, do not produce a suffix effect.

Neath, Surprenant and Crowder (1993), examined the suffix effect in more detail. They attempted to determine whether the suffix could be produced by a not yet categorized sound entering an acoustic storage system, as proposed by the PAS, or if the context in which the stimulus used as a suffix is interpreted, would determine its efficacy. The sound "baa" was used as a suffix. Participants in one condition were led to believe the sound to have been produced by a sheep and in the other condition by a person. Despite the fact that the same physical stimulus was used, greater suffix effects were obtained if the suffix was perceived as a speech sound rather than nonspeech sound. Furthermore a second experiment found that while labeling a suffix as a speech sound and then relabeling it a non speech sound made it lose its strength, the opposite does not work. Thus a suffix that had not been effective could not be made effective by relabeling it speech when it was previously labeled non speech. Thus it appears a suffix must be labeled speech to produce standard suffix effects. Strategies which reduce the effectiveness of suffixes may well involve representations making them "non speech".

Recency and suffix effects have been reported in a variety of other presentation modalities. For example, Shand and Klima (1981), were able to obtain both suffix and recency effects, using deaf subjects, and lists of items presented in American sign language. Furthermore Manning (1980), was able to find recency using tactile presentation. In addition to that, the modality effect has been observed in situations

involving long term memory (Gardiner and Gregg, 1979). However, the results described above are controversial, and it is possible that they may be based on different mechanisms than the one responsible for the standard suffix effect.

The frequency with which a word appears in the English language has been found to have an effect in memory performance. For example, a number of studies have shown that high frequency words are recognized less accurately than low frequency words (Schulman and Lovelace, 1977). Glanzer and Bowles (1976) presented subjects with lists of high and low frequency words. When given a forced choice recognition test, the subjects performed better on the low frequency words. Similarly, when subjects were presented with a second list of words that included some of the original words presented and some distractors, and asked to indicate whether each word was part of the old list or not, performance was reduced for both high frequency targets and high frequency distractors, when compared to their low frequency counterparts. More recently, Chalmers et al. (1997) found similar results of superiority for recognition of low frequency words when compared to high frequency words.

This recognition memory advantage with low frequency words is somewhat surprising since, in a number of other memory tests, the advantage occurs when high frequency words are used. For example, in a lexical decision task, when a string of letters is presented and the subject is asked to decide as quickly as possible if the string of letters form a real word or not, performance is better for high frequency words (Howes and Solomon, 1951). Also recall is found in many cases to be better for high frequency words

than for low frequency words ( Gregg, 1976; Sumbly, 1963). Thus the effect of word frequency on word recall is not clear. It is apparently both dependent on the task, as well as the particular words used.

### THE BADDELEY AND HITCH HYPOTHESIS

Taking quite a different approach than earlier ones, Baddeley and Hitch developed a new way of classifying recency. In a 1993 paper, Baddeley and Hitch argued that evidence gathered from a number of experiments suggest that priming and recency are the result of an implicit memory process. The researchers further argued that in order to support their line of reasoning both recency and priming mechanisms should meet the five criteria proposed by Tulving and Schacter (1990), used to classify a type of learning as being implicit rather than explicit. These criteria are: 1) Intact performance in amnesic patients, which means that the performance of amnesic patients in the learning task being studied would remain the same as for non-amnesic subjects. 2) Developmental dissociation, which means that if the task involves implicit memory then the performance of young children would be similar to the performance of adults, while if the task involves explicit memory then performance would increase as the age of the participant increases. 3) Drug dissociation, meaning that some drugs that have an effect on explicit memory would have no effect on implicit memory. 4) Functional independence refers to the fact that some variables may affect explicit memory tasks but would have no effect on implicit memory tasks, and vice versa. 5) Stochastic independence would occur when explicit memory performance for the retrieval of a specific stimulus is independent of the implicit

memory performance on the same stimulus. Evidence supporting these criteria will be described next, as they apply to priming and recency. If priming and recency act in the same manner with respect to these variables, it would suggest a similar implicit memory base. Any dissociation would argue against it.

First, with respect to intact performance in amnesic patients, there is evidence that in some cases amnesic patients are able to perform as well as normal participants in implicit memory tasks (for examples see Graf, Squire and Mandler, 1984). Furthermore, amnesic patients showed a level of priming that was comparable to the one exhibited by normal participants, even though the amnesic patients could not explicitly remember the priming episode, while the normal participants could. Similarly Wilson and Baddeley (1988), found evidence of a preserved recency effect in amnesic patients, despite impaired performance on memory for items presented earlier in a list.

Second, developmental dissociation between priming and explicit memory is suggested by the fact that Parkin and Streete (1988), among others, found that priming effects in three year olds can be very similar to those observed in college students, while recognition memory increases with age. A similar pattern occurs for the recency effect. In an experiment carried out by Thurm and Glanzer (1971), it was found that younger children performed poorly in their memory for items presented early in a list when compared to older children, but the performance of the two groups was very similar on the memory for items at the end of the list.

Third, experiments such as the one performed by Parker et al. (1983), showed that drugs such as scopolamine and alcohol reduce performance in explicit recall, but have little effect on priming. In a study on the effects of Valium on free recall, Mewaldt et al. (1983) found a similar pattern of results for recency. The drug impaired the recall of earlier items in the list to be recalled, but the level of recency was not affected.

The fourth criterion, functional independence, refers to the fact that some variables that appear to have an effect on episodic memory are found to have no effect on priming, and vice versa. For example, priming is not affected by depth of processing, while recall is greatly affected by it (Jacoby and Dallas, 1981). A similar pattern occurs for recency. For example, the number of stimulus repetitions has an effect on recall of early items in a list but typically recency is not affected (Glanzer, 1972).

Finally, stochastic independence is said to occur when the performance on a particular item in an explicit task is independent of the performance on the same item in an implicit task. The most striking evidence of stochastic independence between priming and explicit memory is the fact that priming effects are as large for items that have been recognized as having been presented in the study phase as for the items that have not been recognized (Tulving et al. 1982).

No known study has explicitly set out to test whether stochastic independence in fact exists between recency and explicit memory, but the results of a study by Baddeley (1968) suggest that it is highly possible. Thus, when the five criteria used to classify a type of learning as implicit were applied to recency, the results were very similar to those

obtained with priming. According to Baddeley and Hitch (1993), the similar results suggest that both priming and recency may result from the same underlying mechanism.

## BACKGROUND AND SIGNIFICANCE

The evidence proposed by Baddeley and Hitch (1993) strongly argue in favor of a possible relationship between priming and recency. However, the Baddeley and Hitch paper presented a compilation of results from a variety of studies and a set of theoretical suppositions. One way to disprove the theory that recency is implicit would be to show one or more dissociations between priming, which is considered implicit, and recency. In order to do this in the most direct way, we attempted to design a study in which priming and recency were tested under the same conditions. This was difficult for a variety of reasons, some of which will be discussed next.

The typical way in which priming is measured is quite different from the typical way in which recency is measured. Usually the recency effect in free recall is measured by looking at the change in probability in recalling stimuli that were presented at the end of the list, as compared to the probability of recalling stimuli that were presented earlier in the list. On the other hand, repetition priming is measured by the facilitation in processing information that is dependent upon the previous presentation of that information. In addition, in tests of explicit memory such as recognition, cued recall, or free recall, the instructions given to the participant are to try to recollect a prior episode. On the other hand, in implicit tests of memory, there are no references to prior episodes, and memory is measured from the changes that occur from baseline performance.

Another problem with data from literature attempting to relate priming and recency, is that the two effects are confounded. A prototypical example of such confounding can be seen in an experiment performed by Rybash and Osborne (1991). The experiment consisted of an implicit word stem completion task. The researchers found that the most recently presented items in the list produced a greater priming effect. Thus, priming was used as a tool in order to measure recency. It is reasonable to conclude that the greater performance for the items presented at the end of the list does not represent the recency effect alone but a combination of recency and priming. In other words, these results only suggest that the recency effect may play a role in priming, when it is measured by a stem completion task, but these results certainly do not suggest anything about whether priming and recency are the result of the same process or not. Consequently, paradigms similar to the one used by Rybash and Osborne cannot be used to test whether priming and recency are related to the same memory process.

Given the potential for confounding, and the different ways the two variables are measured, it appeared to be a challenge to design an experiment in which priming and recency could be tested together.

#### EXPERIMENT 1: The Suffix Conditions

In order to be able to differentiate between priming and the recency effects in the current experiment, a variation of the continuous distractor paradigm was developed. The participants were presented with words in an incidental mode. That is, seven lists composed of a combination of words and numbers were presented to the participants on a

computer screen, one item at the time. Each one of the first six lists (the distractor lists), was composed of six numbers and six words. An example of a distractor list is:

3; MODEL; 8; SPORT; 4; BLIND; 9; LEVEL; 5; AWAKE; 1; SCORE.

The participants were instructed only to read the lists. After each of the first six lists, the participants were asked to recall as many numbers as they could from that list. After the seventh list, contrary to their expectations, the participants were tested on the words presented. Priming was tested by giving half of the participants a stem completion task, while recency was tested through the use of a recall task. That is, half of the participants were asked to recall as many words as they could remember from the last (the seventh) list. This paradigm, unlike previously known paradigms, provides a method of testing for a dissociation between priming and recency. The same stimuli were presented prior to the tests, one which involved priming, and one which involved recency. If the results for priming and recency are similar, one would infer that the two measures stem from the same source. If not, the presence of a dissociation would discredit Baddeley and Hitch's hypothesis.

To further enhance the possibility of a dissociation, the words presented were either high or low frequency words, and the participants were either instructed to read the stimuli aloud or silently. Furthermore, in Experiment 1 a suffix was presented at the end of the seventh list. The rationale behind using these different conditions was to provide possibility for dissociation, since these variables are likely to differentially affect implicit and explicit memory. More specifically, the word frequency condition was chosen because

it was hypothesized that word frequency may differentially affect priming and recency. For example Rajaram and Neely (1992), found that when they tested implicit memory with a lexical decision task and explicit memory with a recognition task, lexical decision performance was better for high than for low frequency words, while recognition was equivalent in the two frequency conditions. On the other hand Kinoshita (1995) found no low frequency recognition advantage but, under the same conditions, found that low frequency words produced greater repetition priming in a lexical decision task than high frequency words.

Similarly, the presentation modality variable was selected because, as suggested by Roediger and Blaxton (1987), the relationship between the physical format and test format appear to have a large effect on implicit memory, with similarity of format between presentation and test enhancing implicit memory. In addition, the presentation modality is linked to a specific effect in explicit memory, called the modality effect (Baddeley, 1990). This effect refers to the fact that recall is better when presentation is auditory as opposed to visual. Again these results suggest that priming and recency may also be affected differently by the modality of presentation.

Furthermore, the suffix condition was chosen as a dissociation factor because the suffix effect, that is the disruption of recency caused by the presentation of a not to be recalled item at the end of a list (Baddeley, 1990), is a well established phenomenon in the explicit memory literature, but it is not expected to have a strong effect on implicit memory tasks.

Unlike any previous study in the literature, this experiment allows for a direct comparison between priming and recency, measuring the two effects separately, but under the same conditions of stimulus presentation. Thus, this is the first experiment to provide direct evidence to support or contradict the hypothesis advanced by Baddeley and Hitch (1993). If the results for priming and recency are found to be similar in the different conditions, then it may be inferred that the results are due to the fact that priming and recency are both mediated by the same mechanism, suggesting that the Baddeley and Hitch (1993) hypothesis may be correct. On the other hand, if the different conditions produce a dissociation, that is if different results are obtained between the priming and recency effects in the different conditions, then it would be likely that these effects do not result from the same underlying process, suggesting that the Baddeley and Hitch hypothesis may not be correct.

## Method

### Participants

Participants in this Experiment (44 males and 148 females) were recruited at Hunter College of the City University of New York. All 192 participants were between 18 and 35 years of age, and had English as their first language.

### Experimental Design

A schematic representation of the conditions in Experiment 1 is presented in Table 1. The experiment is a 2 Task (priming and recency) X 2 Modality (auditory and visual) X 2 Frequency (high and low) between subjects factorial design. Half the participants were

assigned to the recall condition, and the other half to the stem completion condition. As can be seen in Table 1, within the recall and the stem completion conditions, half the participants were assigned to the auditory condition, and the other half to the visual condition. Finally, within the auditory and the visual conditions, half the participants were assigned to the high frequency condition, and half to the low frequency condition. Thus, this 2 X 2 X 2 between subjects design resulted in eight conditions, which are: Recall auditory high frequency; Recall auditory low frequency; Recall visual high frequency; Recall visual low frequency; Stem completion auditory high frequency; Stem completion auditory low frequency; Stem completion visual high frequency; Stem completion visual low frequency.

Table 1

Conditions in Experiment 1: The Suffix Conditions

		TASK							
		RECALL				STEM COMPLETION			
MODALITY		AUDITORY		VISUAL		AUDITORY		VISUAL	
	FREQUENCY		HIGH	LOW	HIGH	LOW	HIGH	LOW	HIGH

### List Construction

The distractor lists will be described first, followed by the target lists. The words used in the six distractor lists may be seen, in their original order of presentation, in Appendix A. The Thorndike and Lorge (1944), norms were used to construct the lists. All 36 words used in the distractor lists were five letters in length. These words were selected because they were listed by Thorndike and Lorge as having a frequency of occurrence in the English language ranging between 50 and 100 per million. This frequency range was chosen because it was between the frequencies of the high and the low frequency target words. The words used in the two target lists were also taken from the Thorndike and Lorge list of English words. Of the two target lists, one was composed of high frequency words that were rated among the most frequently occurring 500 words. These words were chosen because their initial three letters were different from each other, as well as different from the first three letters of the words in the distractor lists. The high frequency words were:

WATER. SOUND. PARTY. COLOR. STATE. MONEY.

The other target list was composed of low frequency words, that were rated as having a frequency ranging between 10 and 20 per million. The words in the low frequency target list were chosen because their initial three letters were different from each other, different from the first three letters of the words in the distractor lists, as well as different from the first three letters of the high frequency words. The low frequency words were:

APRON, FLUID, TORCH, BACON, SCARF, PANEL.

Within the high frequency and the low frequency lists, the words were chosen so that the stems of each word (the first three letters), could be used to produce an approximately equal number of English words.

All participants were presented with six initial lists, composed of six words and six digits each. All the stimuli in the lists were presented in a sequence of number, word, number, word, ....etc. The target list was composed of six words and seven numbers. The following is an example of the stimuli presentation in the target list:

4. WATER, 7. SOUND, 3. PARTY, 9. COLOR, 5. STATE, 8. MONEY, 2.

All the lists ended with a word, except the target list, which ended with a number. The last number presented was introduced to provide a suffix for the recall of the words.

The six initial lists were presented in the same order to all participants, while the target lists were counterbalanced in a way that within a group of participants each word was presented once in every position, and followed another specific word only once. This counterbalancing method produces six lists per condition.

### Procedure

All the stimuli were presented on a Relisys 14" monochrome display monitor. A customized software program generated the list of words to be presented in the appropriate order. Each stimulus was presented for 1.5 sec., and the inter-stimulus interval was .5 sec. The inter-list interval was 15 sec. Each stimulus was presented in the center of

the screen in capital letters, and the approximate distance between the participant and the screen was 40 cm.

Participants were seated in front of the computer screen and instructed to read the stimuli that would appear on the screen silently, if they were in the visual condition, or aloud, if they were in the auditory condition.

Participants were further instructed that after the presentation of each list the experimenter would tell them what to do. They were then presented with the distractor lists. At the end of each of the six distractor lists, the participants were asked to write down as many numbers as they could remember from the previous list. Then, after the presentation of the seventh list, which was the target list, if the participants were in the recall condition, they were asked to write down as many words as they could remember from the last list, while if they were in the stem completion condition they were asked to complete a stem completion list with the first appropriate word that came into their mind for each stem. This list included stems that could be completed using target words.

The stem completion list was composed of 24 stems, and included the six stems that could be used to compose the high frequency words, as well as the six stems that could be used to compose the low frequency words. The list was counterbalanced in this way so that in the stem completion condition, the participants that were presented with the high frequency words filled in the stems for the high frequency words, as well as the ones for the low frequency words. The same was done for the participants in the low frequency condition. This was done so that a baseline for the stem completion of the target lists

could be derived. The baseline was measured by the frequency of occurrence with which the participants completed the stems with the appropriate target word when they had never seen it before.

In the recall condition, the participants were presented with the stimuli in the same order of presentation as the stem completion condition. The only difference was that at the end of the lists, the participants were asked to recall as many words as they could from the last list presented (the target list). Following either the recall or the stem completion task all participants were asked to perform several other tasks, and the results of these tasks will be discussed in a separate section.

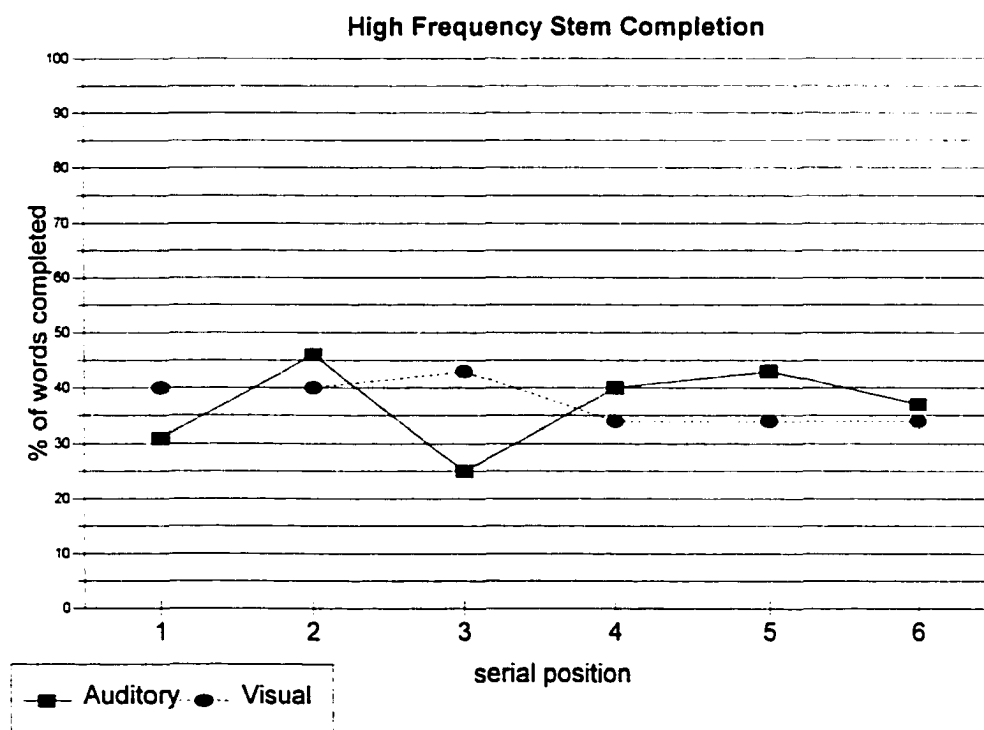
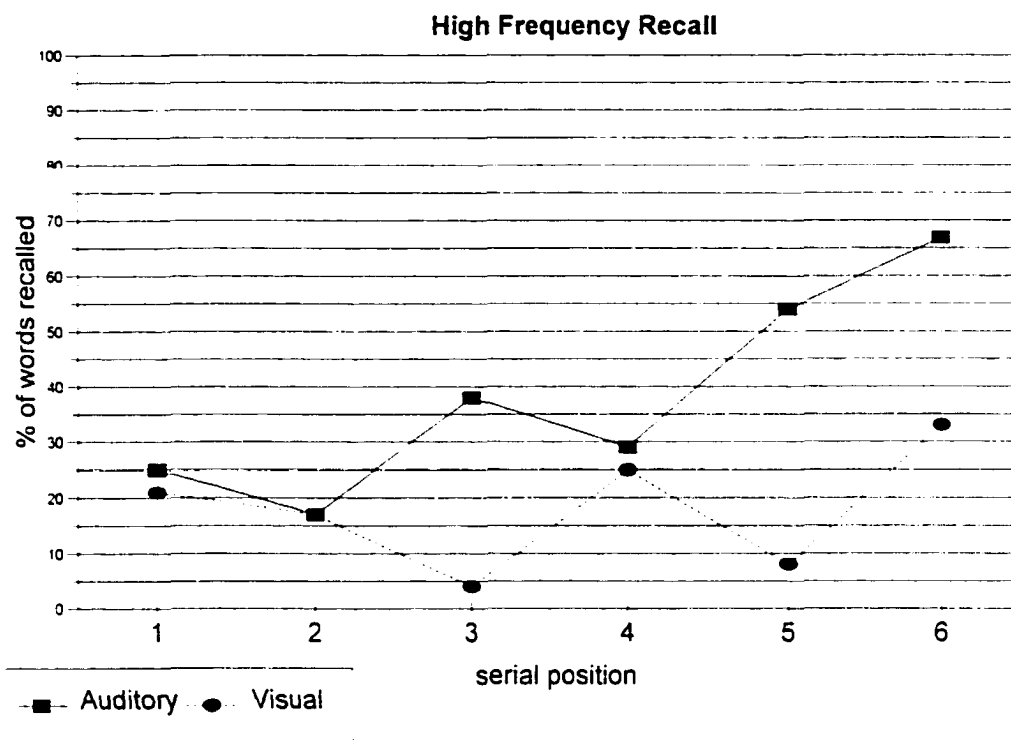
First, all the participants were asked to write down all the words that they could remember that were presented during the experiment. This task provides a measure of long term recall for the words presented in the distractor lists in the recall condition, and in the stem completion condition it also gives a measure of memory for the target words. Participants in the recall condition were presented with a second additional task. They were asked to complete the stem completion list that could be completed with the target words. A direct comparison between the target words recalled and the target words used in the stem completion task could then be made. As a final additional task, all participants were asked to complete a stem completion list that could be completed with some of the words presented in the first six lists. This provides a measure of priming for the distractor lists. Finally, all the participants were asked if during the presentation of the target list they

were focusing their attention on the words, on the numbers, or both. Participants that reported focusing their attention solely on the words were excluded from the analysis.

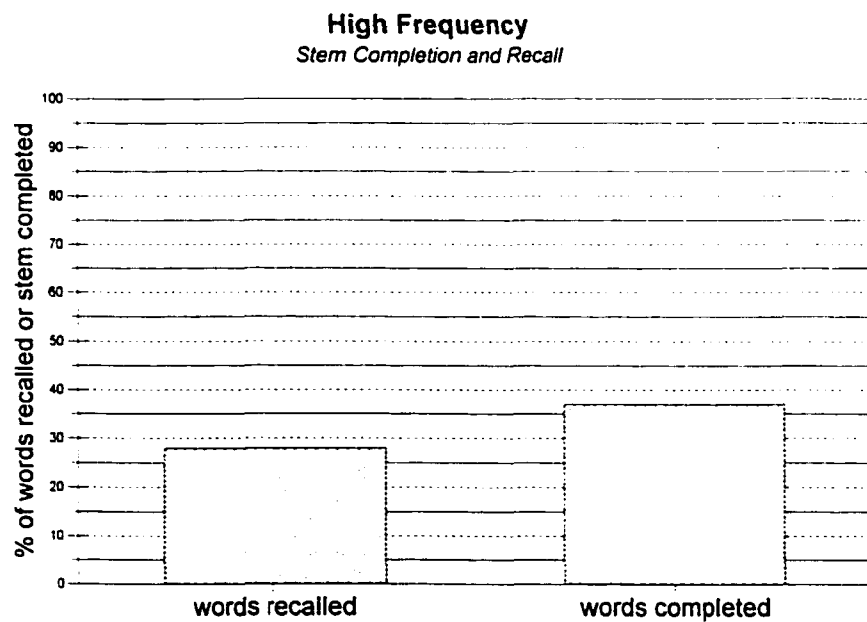
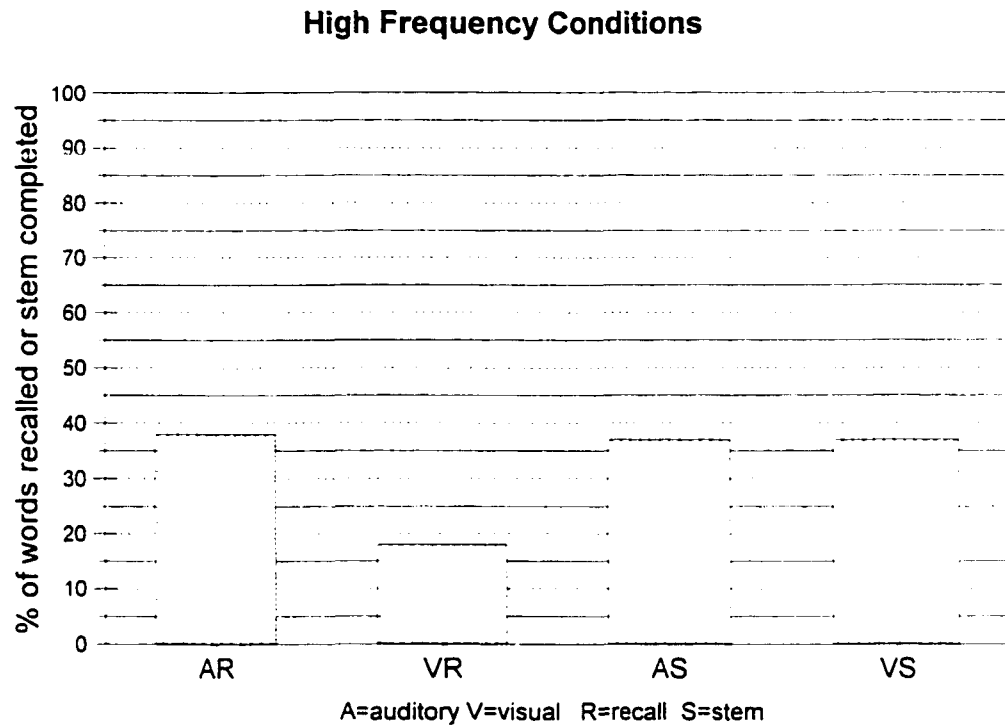
## DESCRIPTIVE RESULTS

The results regarding the number of target words recalled, as well as the number of stems completed using the words presented in the target list, were tallied for each serial position, for each presentation modality and word frequency conditions. Figures 1a and 1b are graphic representations of these results for the high frequency condition, while Figures 1c and 1d are representations of the results for the low frequency condition. In all conditions, the priming measure was adjusted by subtracting the baseline level of priming from the number of stems completed, in order to obtain a pure measure of priming. The baseline level for the target words was obtained using 288 participants, 144 from Experiment 1, and 144 from Experiment 2.

**Figure 1a: Serial Position Results from the High Frequency Conditions in Experiment 1**



**Figure 1b: Composite Results from the High Frequency Conditions in Experiment 1 (All Serial Positions)**



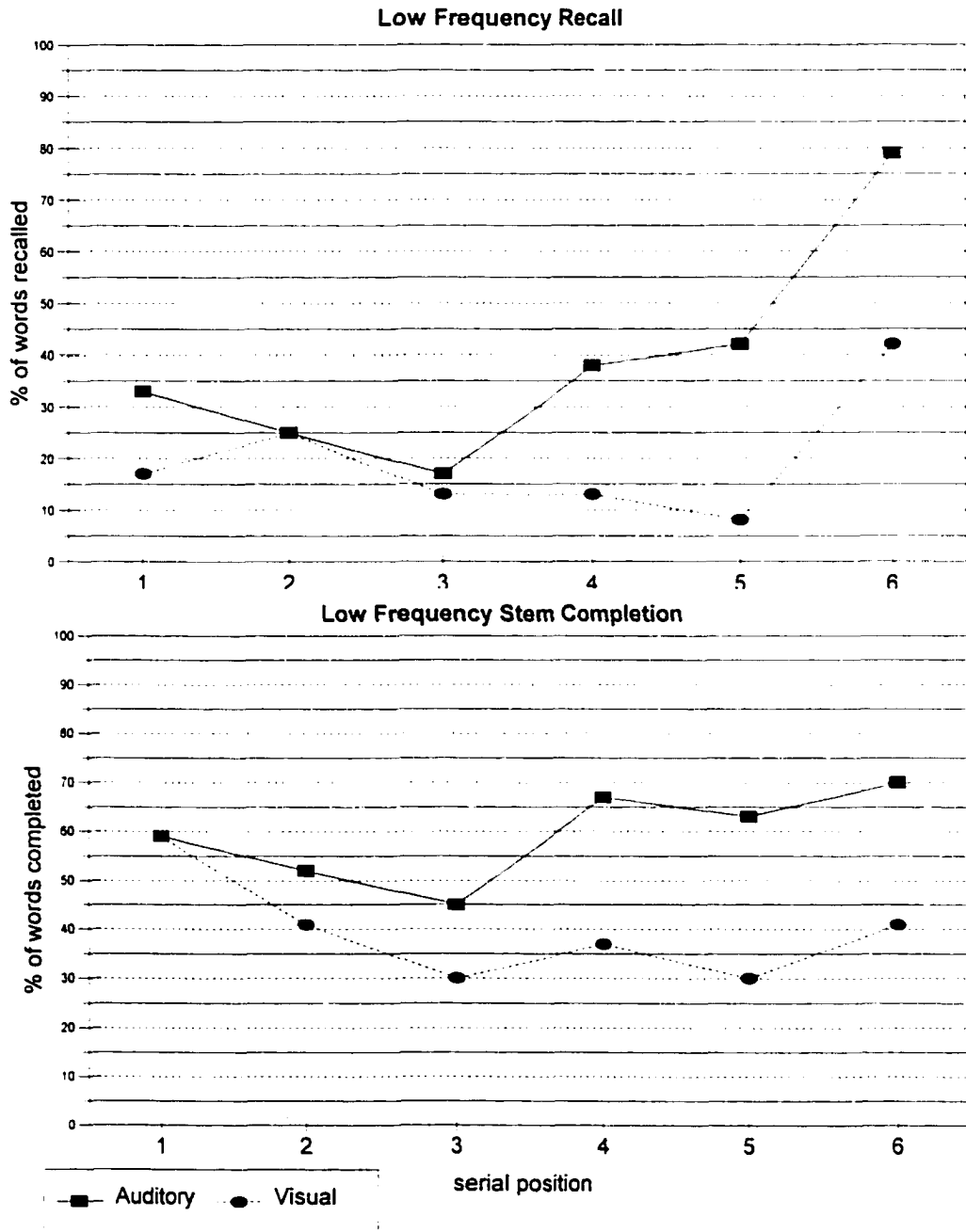
The baseline priming level for low frequency words was 11%, while the baseline priming level for the high frequency words was 26 %. Of the 864 stems that could be completed with the low frequency target words, 95 were actually completed with these words. On the other hand, 225 of the possible 864 stems were completed using the high frequency target words. A Chi-square test for the stems completed with the high and low frequency words was significant,  $\chi^2(1) = 63.82$ ,  $p < .001$ . This shows that high frequency words were used significantly more often than low frequency words to complete the possible stems, when those words had not been presented before to the participants.

The serial position curves for the high and low frequency recall auditory conditions, depicted in the upper portion of Figures 1a and 1c, show that the words presented in the last position were recalled better than the words presented in the middle of the list. On the other hand, the serial position curves for the recall visual conditions do not show such good performance in position 6. The stem completion conditions both visual and auditory, for both the high and low frequency conditions, are rather flat, that is the amount of priming in the different positions did not differ markedly.

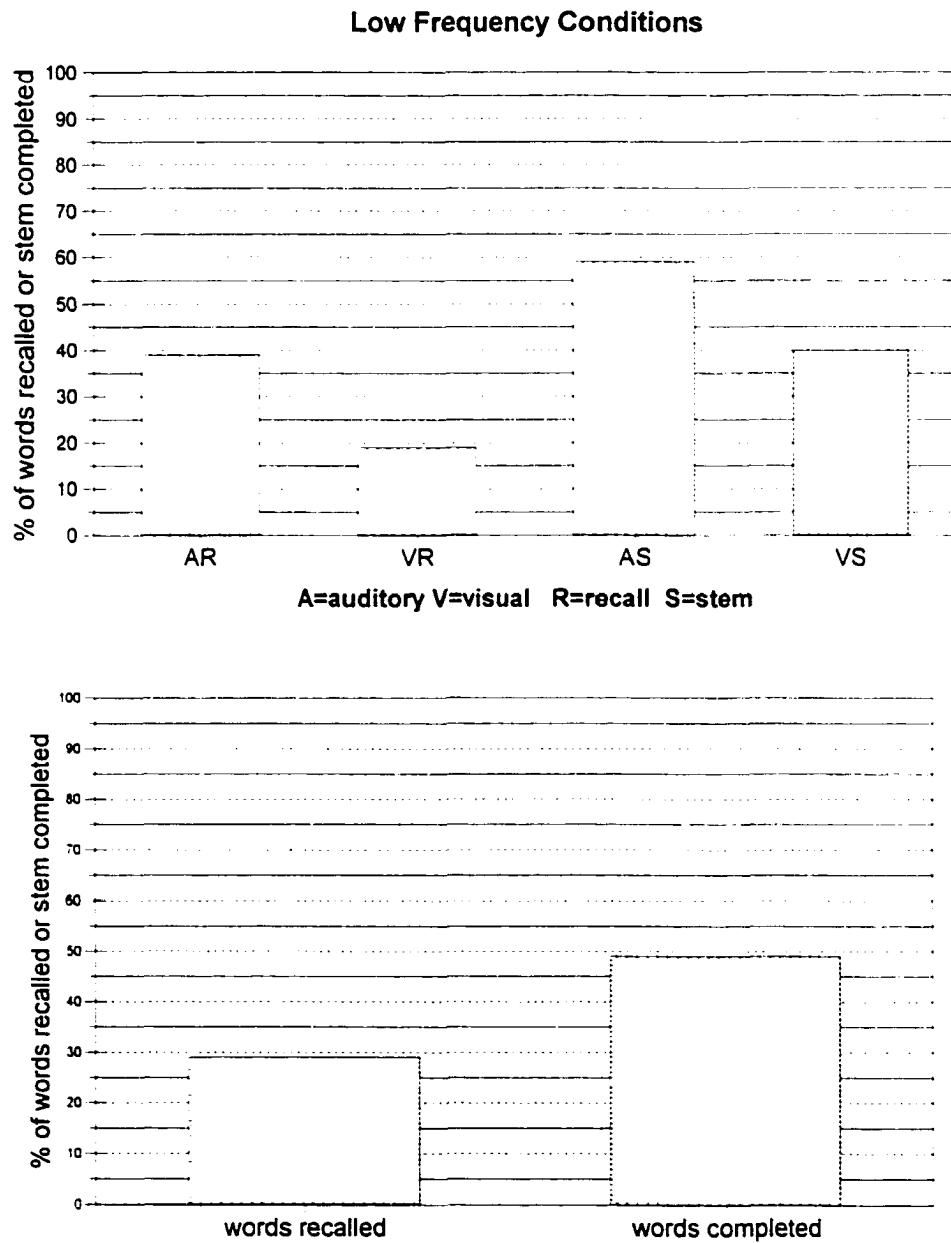
The upper portions of Figures 1b and 1d represent the amount of stem completion and recall, in all the conditions, when summed across all the serial positions. As can be seen in these graphs, performance in both recall and stem completion was better in the auditory as opposed to the visual conditions, with the exception of stem completion in the high frequency condition. In this condition the amount of stem completion did not differ markedly between the visual and the auditory modalities.

Finally, the graphs in the lower right portion of Figures 1b and 1d represent the amount of recall and priming, when summed across the auditory and visual modalities. For both, high and low frequency words, priming was better overall than recall, and the difference between recall and priming was much more pronounced in the low frequency than in the high frequency conditions.

**Figure 1c: Serial Position Results from the Low Frequency Conditions in Experiment 1**



**Figure 1d: Composite Results from the Low Frequency Conditions in Experiment 1  
(All Serial Positions)**



## METHOD FOR EVALUATING PRIMING AND RECENCY

The results presented thus far do not address the need to directly compare priming and recency in the different conditions. A method is therefore needed to directly compare the two effects. Recency was calculated by comparing, for each participant in the recall condition, whether they had correctly recalled the word presented in position 6 of the target list (list 7), to whether they had recalled words presented in the middle of that list, (position 3 and 4). If the participant recalled the word presented in position 6, and did not recall any words from position 3 and 4, or if the word presented in position 6 was recalled but only one of the words presented in positions 3 and 4 were recalled, then the participant was regarded as having shown recency. On the other hand if the participant's recall of words presented in positions 3, 4 and 6 did not differ (all the words were recalled or none were recalled), or recall in positions 3 and 4 was better than in position 6, then the participant was regarded as not having shown recency. Thus the recency measure for a particular group condition was the percentage of subjects showing recency based on these criteria.

Priming was calculated by comparing the amount of appropriate stem completions shown by participants in the priming condition, to the amount of appropriate stem completion shown by the baseline (participants that were never presented with the target words but were given the stems that could be filled using such words). The baseline level for stem completion for the high frequency words was 26%, while the baseline level of stem completion for the low frequency words was 11%. Because of these baseline values,

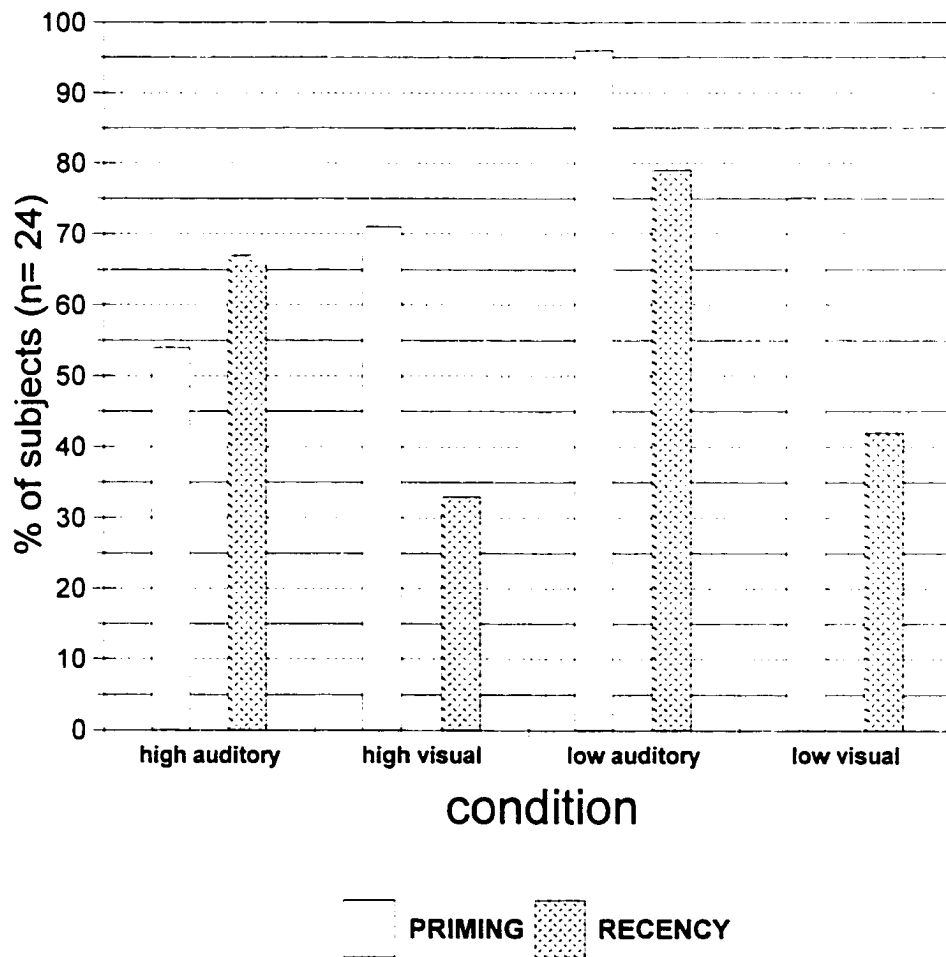
since each list was composed of six words, the baseline stem completion level for the low frequency list was estimated to be 1 word (16.6% of the six words), and the baseline stem completion level for the high frequency list was estimated to be 2 words (33.3% of the six words). Thus if a participant in the low frequency condition filled in 2 stems or more with the appropriate, previously presented words, then the participant was regarded as having shown priming. Similarly if a participant in the high frequency condition filled in 3 or more stems with the appropriate, previously presented words, then that participant was regarded as having shown priming.

The rationale behind such scoring procedures was that it would allow for a direct comparison of priming and recency in the different conditions. Thus, if priming and recency are part of the same implicit memory process, and recency was found to be higher in the auditory high frequency condition in comparison to the visual high frequency condition then, the same pattern of variation should be expected for priming. Otherwise it could be argued that the two effects are not part of the same implicit memory process.

The results for the eight conditions in Experiment 1 are depicted in Figure 1e. In this figure if we only consider the low frequency condition, then the number of participants showing recency appear to be parallel to the number of participants showing priming. In fact, both priming and recency are greater in the auditory as opposed to the visual condition. In addition, in both the auditory and visual low frequency conditions, priming is larger than recency. When we include the high frequency condition, however, there appears to be evidence for a dissociation between priming and recency.

In fact, in the high frequency condition, recency still shows an auditory superiority effect, with a greater number of participants showing recency in the auditory as opposed to the visual condition. On the other hand, priming follows an opposite pattern, with fewer participants showing priming in the auditory as opposed to the visual condition. In addition to that, and contrary to every other condition, in the high frequency auditory condition, the number of participants showing recency is greater than the number of participants showing priming.

**Figure 1e: Priming and Recency in Experiment 1 ( The Suffix Conditions)**



## LOG LINEAR ANALYSIS

The nature of the data obtained, that is, the number of participants showing priming and recency in the different conditions, limits the type of inferential statistics that can be performed on the data. According to Kennedy (1983), the analysis of qualitative/categorical data has always been an important component of behavioral research. Unfortunately, however, until recently the analysis of such data was limited to the context of two dimensional tables, using chi-square goodness of fit procedures. A number of researchers recognized the need for a statistical method that allowed for the simultaneous analysis of multidimensional contingency tables. This statistical method came to be known as log-linear analysis.

According to Kennedy (1983), the interpretation of the results in log-linear analysis differs depending on whether the type of inquiry is symmetrical or asymmetrical. If we have two qualitative variables, like sex of the participant (male/female), and attitude toward an amendment (oppose/support), there are two types of questions that are likely to be asked in a research setting.

First of all, one could ask whether the two variables are independent as opposed to correlated. Independence, or lack of association, between the two variables, would indicate a close similarity between the preferences of males and females toward the amendment. The same results could also be explained by saying that persons who have expressed their view either in favor of or against the amendment are equally represented, in a proportional sense, by males and females. It is clear that in this mode of inquiry it

would not be appropriate to designate one of the variables as independent or explanatory, and the other as dependent or a response variable. Thus, hypotheses dealing only with the presence or absence of an association between variables can be approached bilaterally, and this type of inquiry is called symmetrical.

The second, and completely different type of question that could be asked would be to determine whether there is a difference in the preferences of males and females toward the amendment. In this case the sex variable assumes the status of independent variable, while the attitude toward the amendment becomes, in effect, a dependent variable. This perspective is unidirectional, and this type of inquiry is called asymmetrical.

Clearly the type of inquiry in the present study is asymmetrical in that the condition in which a participant was presented with the stimuli was an explanatory or independent variable, and the outcome of their response, that is, whether they were classified as having shown priming (if they were in the priming condition), or recency (if they were in the recall condition), was unequivocally a response or dependent variable.

When the method of inquiry is asymmetrical, a subset of the log-linear models is used, called logit-model analysis. Kennedy (1983), argued that in many respects a logit-model of analysis is similar to an ANOVA. In fact, Kennedy suggests a number of logit models that would make the interpretation of the results similar to interpretation of an ANOVA summary table. For the purpose of the current experiment an analysis of a four dimensional table was performed.

In Experiment 1, there are three explanatory variables and one response variable. The three independent variables, all of which are dichotomous, are: Task (priming, recency), Modality (auditory, visual) and Frequency (high, low), while the response variable, which is also dichotomous, is Outcome (yes for classifying a participant as having shown recency or priming, or no for not having shown it). Interpretation of the results is similar to an ANOVA in that they range from no effect, to main effects for each one of the explanatory variables, to three possible first-order interaction effects, to a second-order interaction effect.

## RESULTS AND DISCUSSION

Table 2 shows the frequencies and percentages for each condition of Experiment 1. For each Task (priming and recency), there are two levels of Frequency (high and low), two levels of Modality (auditory and visual) and two levels of Outcome (yes and no). Since the log-linear analysis performed on the results obtained in Experiment 1 is based on the results from all the conditions, the percentages depicted in Table 2 are based on the total number of participants in Experiment 1, which is 192.

Table 2

**Observed Frequencies For the Log-Linear Analysis of Experiment 1**

	OUTCOME	MODALITY	FREQUENCY	TASK		
				PRIMING	RECENCY	TOTAL
Y E S	AUDITORY	HIGH	13 ( 6.77)	16 ( 8.33)	29 (15.10)	
		LOW	23 (11.98)	19 ( 9.89)	42 (21.87)	
		<b>TOTAL</b>	<b>36 (18.75)</b>	<b>35 (18.23)</b>	<b>71 (36.98)</b>	
	VISUAL	HIGH	17 ( 8.85)	8 (4.16)	25 (13.02)	
		LOW	18 ( 9.37)	10 (5.20)	28 (14.58)	
		<b>TOTAL</b>	<b>35 (18.23)</b>	<b>18 (9.37)</b>	<b>53 (27.60)</b>	
	<b>SUM OF TOTALS FOR YES</b>			<b>71 (36.98)</b>	<b>53 (27.60)</b>	<b>124 (64.58)</b>
	N O	AUDITORY	HIGH	11 (5.73)	8 (4.16)	19 ( 9.89)
			LOW	1 (0.52)	5 (2.60)	6 ( 3.12)
			<b>TOTAL</b>	<b>12 (6.25)</b>	<b>13 (6.77)</b>	<b>25 (13.02)</b>
VISUAL		HIGH	7 (3.64)	16 ( 8.33)	23 (11.98)	
		LOW	6 (3.12)	14 ( 7.29)	20 (10.41)	
		<b>TOTAL</b>	<b>13 (6.77)</b>	<b>30 (15.62)</b>	<b>43 (22.39)</b>	
<b>SUM OF TOTALS FOR NO</b>			<b>25 (13.02)</b>	<b>43 (22.39)</b>	<b>68 (35.41)</b>	
<b>GRAND TOTAL</b>					<b>192 (100)</b>	

Note: Percentages are in parenthesis.

Table 3 is a summary of the results from the logit-model analysis of the data depicted in Table 2. The models used in the analysis are shown in the left portion of Table 3, together with the  $\chi^2$  value for that model. The right side of Table 3 represents the derived value for each of the three main effects, each of the three first-order interaction effects, and the second-order interaction effect. The derived effects are obtained by subtracting the  $\chi^2$  value of each model from the previous one.

For example, in order to obtain the  $\chi^2$  value of the main effect of Frequency, labeled "FO" in Table 3, the  $\chi^2$  value of the model "TFM TO FO", which is 20.39, is subtracted from the  $\chi^2$  value of the model "TFM TO", which is 26.50, resulting in a significant main effect of Frequency,  $\chi^2(1)= 6.11, p<.05$ . This main effect is due to the difference in the number of participants showing recency and priming combined, between the high and the low frequency conditions. More specifically, recency and priming were found in 71 participants in the low frequency conditions, and in 54 participants in the high frequency condition (see Table 2). Thus, the priming and recency effects combined were found to occur more often when the words used as stimuli are low frequency rather than high frequency.

By closely observing Table 2, it is apparent that the main effect of Frequency is driven by the difference in priming effects found in the auditory high frequency condition and the auditory low frequency condition, where priming was observed in 13 and 23 participants respectively. A comparison of these two conditions was done using a Fisher

Exact test. The Fisher Exact test calculates an exact probability value for the relationship between two dichotomus variables. The comparison between the two conditions was found to be significant,  $p = .001$ .

Table 3a illustrates the four Fisher Exact tests performed between the high and the low frequency conditions. As can be seen, only the test performed between the high and the low frequency auditory priming conditions was found to be significant. As previously discussed, the effects of word frequency on memory in general are not well understood. However, a number of researchers have shown a low frequency advantage in recognition memory (Dennis, 1995; Schulman and Lovelace, 1970). It could be argued that a stem completion task is somehow analogous to a recognition task, because in order to complete a stem, participants have to "recognize" that stem as belonging to a particular word. If that is the case, the low frequency advantage found in the literature would support the results found in this experiment.

Table 3

**Results of the Logit Model Analysis of Experiment 1**

<u>Model</u>	$\chi^2$	<u>df</u>	<u>Effect of</u>	$\chi^2$	<u>df</u>
TFMO	0.0	0			
TFM TFO TMO FMO	2.77	1	TFMO	2.77	1
TFM TFO TMO	6.05	2	FMO	3.28	1
TFM TFO MO	10.67	3	TMO	4.62*	1
TFM TO FO MO	12.37	4	TFO	1.70	1
TFM TO FO	20.39	5	MO	8.02*	1
TFM TO	26.50	6	FO	6.11*	1
TFM O	33.94	7	TO	7.44*	1

note:

\* p &lt; .05.

## Legend:

T = task (priming, recency)  
 F = frequency (high, low)  
 M = modality (auditory, visual)  
 O = outcome (yes, no)

The log-linear analysis in Table 3 also shows a main effect of Modality, with 70 participants exhibiting priming and recency effects in the auditory conditions, while only 53 participants showed priming and recency in the visual conditions,  $\chi^2(1) = 8.02$ ,  $p < .05$ . By observing the data depicted in Table 2 it is possible to see that this main effect of Modality is mainly due to the difference between the amount of recency found in the auditory and the visual conditions. Table 3b is a representation of the four Fisher Exact tests performed between the four auditory and visual conditions. The Fisher Exact test performed on the data from the recency high frequency condition was significant,  $p = .042$ . The test performed on the data in the recency low frequency condition was also significant,  $p = .017$ . On the other hand, the analysis of the data in the two priming conditions were not significant, for priming high frequency,  $p = .371$ , and for priming low frequency,  $p = .097$ . These results were not surprising because auditory superiority is a well established phenomenon in the literature on recency, while in the priming literature the modality of presentation per se does not appear to produce any effect.

Table 3 also reveals a significant main effect of Task, indicating that priming and recency are significantly different from each other, when summed across Modality and Frequency,  $\chi^2(1) = 7.44$ ,  $p < .05$ . As may be seen in Table 2, in the sum of the totals for the yes outcome, 71 participants showed priming effects, while only 53 showed recency. Thus, the main effect of Task is due to the greater overall amount of priming, when compared to recency. A closer examination of Table 2 shows that the greatest difference between the priming and recency effects are found in the visual high frequency and the

visual low frequency conditions. The four Fisher Exact tests performed on the amount of priming versus the amount of recency in the four conditions in Experiment 1 are depicted in Table 3c, and indicate that there was a significant difference in the visual high frequency condition,  $p = .019$ , and in the visual low frequency condition,  $p = .039$ , while no significant difference between priming and recency was found in the two auditory conditions. In both the high and low frequency visual conditions, the significant difference between priming and recency is driven by the lower amount of recency found in the visual conditions, as compared to the amount of priming found in the same conditions. In the visual high frequency condition, 17 participants showed priming, and only 8 showed recency. Similarly, in the visual low frequency condition, 18 participants showed priming and only 10 showed recency. Thus, as previously mentioned, the data reflects the expected auditory superiority effect that is typical of the literature on recency, while priming does not appear to be affected by presentation modality.

For both the priming and the recency measures, in order to obtain a positive outcome, that indicated the presence of the priming or the recency effects, the level of priming or recency had to exceed criterion levels. For priming that level had been obtained by using the baseline performance of participants who were not presented with the target words. Participants were rated as having shown priming if the number of target words used in the stem completion task was greater than the baseline level.

For recency, the criterion level was the average from the recall of the words presented in the middle of the list, so that the recall at the end of the list had to exceed the

recall in the middle of the list. Since both methods are consistent with the definitions of priming and recency effects, the significant difference suggested by the main effect of Task could be used as an indication that the priming and recency effects may be part of different processes. However, since it is possible that this difference may be produced simply by a different sensitivity between the methods of assessing priming and recency, an even stronger argument in support of a dissociation would follow from the presence of a significant interaction effect.

Table 3a

**Results of Fisher Exact Tests Performed Between the High and Low Frequency  
Conditions of Experiment 1**

## Priming Auditory Condition

	Outcome Yes	Outcome No
High Frequency	13	11
Low Frequency	23	1

Fisher Exact  
 $p = .001$

## Recency Auditory Condition

	Outcome Yes	Outcome No
High Frequency	16	8
Low Frequency	19	5

Fisher Exact  
 $p = .517$

## Priming Visual Condition

	Outcome Yes	Outcome No
High Frequency	17	7
Low Frequency	18	6

Fisher Exact  
 $p = 1$

## Recency Visual Condition

	Outcome Yes	Outcome No
High Frequency	8	16
Low Frequency	10	14

Fisher Exact  
 $p = .197$

Table 3b

**Results of Fisher Exact Tests Performed Between the Auditory and Visual  
Conditions of Experiment 1**

Priming High Frequency Condition

	Outcome Yes	Outcome No
Auditory	13	11
Visual	17	7

Fisher Exact  
 $p = .371$

Priming Low Frequency Condition

	Outcome Yes	Outcome No
Auditory	23	1
Visual	18	6

Fisher Exact  
 $p = .097$

Recency High Frequency Condition

	Outcome Yes	Outcome No
Auditory	16	8
Visual	8	16

Fisher Exact  
 $p = .042$

Recency Low Frequency Condition

	Outcome Yes	Outcome No
Auditory	19	5
Visual	10	14

Fisher Exact  
 $p = .017$

Table 3c

**Results of Fisher Exact Tests Performed Between the Priming and Recency Conditions of Experiment 1**

## Auditory High Frequency Condition

	Outcome Yes	Outcome No
Priming	13	11
Recency	16	8

Fisher Exact

p= .555

## Auditory Low Frequency Condition

	Outcome Yes	Outcome No
Priming	23	1
Recency	19	5

Fisher Exact

p= .188

## Visual High Frequency Condition

	Outcome Yes	Outcome No
Priming	17	7
Recency	8	16

Fisher Exact

p= .019

## Visual Low Frequency Condition

	Outcome Yes	Outcome No
Priming	18	6
Recency	10	14

Fisher Exact

p= .039

The log linear analysis in Table 3 shows a significant interaction between Task and Modality  $\chi^2(1) = 4.62, p < .05$ . This is of great importance in providing evidence of a critical dissociation between priming and recency. This significant interaction suggests that the degree of priming and recency is different for the auditory and the visual conditions. These difference, as shown in Figure 2, is due to the greater amount of priming than recency in the visual condition, while the difference between priming and recency in the auditory condition is negligible.

As may be seen in Table 2, of the 48 participants in the visual priming condition, 35 showed priming, while of the 48 participants in the visual recency condition only 18 showed recency. Table 3d is a representation of the two Fisher Exact tests that resulted from the comparison of priming and recency in the auditory and visual conditions. Priming and recency were significantly different in the visual conditions,  $p = .0009$ , while there was virtually no difference between priming and recency in the auditory condition,  $p = 1$ .

**Figure 2: Experiment 1: Interaction of Task by Modality**

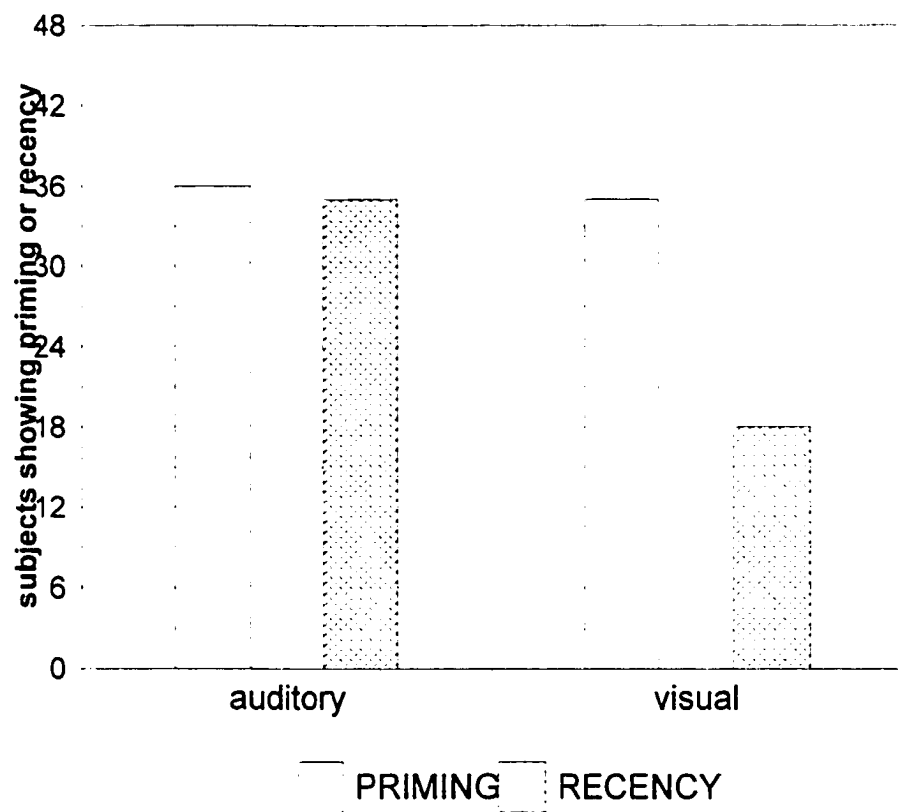


Table 3d

**Results of Fisher Exact Tests Performed Between the Priming and Recency Conditions in the Two Presentation Modalities in Experiment 1**

Auditory Condition

	Outcome Yes	Outcome No
Priming	36	12
Recency	35	13

Fisher Exact

 $p = 1$ 

Visual Condition

	Outcome Yes	Outcome No
Priming	35	13
Recency	18	30

Fisher Exact

 $p = .0009$

The significant interaction between Task and Modality is due to the fact that modality of presentation does not have an effect on priming, since the level of priming is the same in the auditory and the visual conditions. On the other hand, as expected, modality has an effect on recency, with the well established modality effect, whereby more recency is produced in the auditory as opposed to the visual condition.

Part of the results described appear to be contradicted by literature suggesting that priming is increased when the physical structure of the stimulus during presentation closely resembles the physical structure of the stimulus during a task (see Roediger and Blaxton, 1987). According to this hypothesis, if the task is visual as it is in the current experiment, the visual presentation of stimuli should produce greater priming than auditory presentation. This apparent discrepancy may be explained by the fact that the auditory presentation in this Experiment was not solely auditory, e.g., through headphones, but was both auditory and visual, since the participants were asked to read the stimuli that were presented on the computer screen aloud. This type of presentation is rare in the implicit memory literature, but is typical in the recency literature. Crowder (1970), reported that, with respect to recall, this auditory presentation with a visual component does not differ significantly from an auditory presentation without the visual component.

If the priming and recency effects were parts of the same implicit memory process we would expect them to be affected in the same way by the same variable. Thus, the Baddeley and Hitch (1993) hypothesis that priming and recency effects are parts of the same implicit memory process is contradicted by the results of Experiment 1, and more

specifically by the fact that modality of presentation affects priming and recency in a different way. When we take into consideration the results from Experiment 1, we therefore find evidence that indicates a dissociation between priming and recency, suggesting that the two effects are not parts of the same implicit memory process.

## EXPERIMENT 2: The Non-Suffix Condition

Because the digit presented at the end of the target list could act as a suffix, and could therefore diminish the level of recency produced, an additional experiment was performed. We did not expect recency to be diminished because the suffix was a digit and the target was a word list. As previously discussed, Watkins and Peynircioglu (1983) presented words of three different categories within the same list and obtained three recency effects. Thus the last word presented did not act as a suffix for the words from different categories presented before it. In addition, Gardiner and Gregg (1979) found no suffix effect when the suffix was provided by instructing the participants to count backwards, before and after each to-be-remembered item, including the last one.

The evidence reported suggests that, when information from different categories is presented within the same list, the item presented last does not reduce recency in the other category. Thus, it follows that the digit presented at the end of the target list in Experiment 1 should not produce a suffix effect in the target words. Nonetheless it seemed appropriate to confirm this assumption. Therefore, in Experiment 2 the procedure was modified by eliminating the digit at the end of the target list. Experiment 1 will be referred to as the suffix condition, while Experiment 2 will be referred to as the non-suffix condition.

### Method

#### Participants

Participants for Experiment 2, (30 males and 114 females) were recruited at

Hunter College of the City University of New York. All 144 participants were between 18 and 35 years of age, and had English as their first language.

### Experimental Design

The conditions of Experiment 2 were the same as those in Experiment 1, and may be seen in Table 1. The experiment is a 2 Task (priming and recency) X 2 Modality (auditory and visual) X 2 Frequency (high and low) between subjects factorial design.

### List Construction

The lists of stimuli used in Experiment 2 were the same as those used in Experiment 1, with the exception that the target list ended with a word as opposed to a number. An example of a target list used in Experiment 2 is:

WATER, 7, SOUND, 3, PARTY, 9, COLOR, 5, STATE, 8, MONEY

This differs from Experiment 1, where the sequence would have been:

WATER, 7, SOUND, 3, PARTY, 9, COLOR, 5, STATE, 8, MONEY, 2

### Procedure

All stimuli were presented on a Relisys 14" monochrome display monitor. A customized software program generated the list of words to be presented in the appropriate order.

The stimuli, order of presentation, timing, and type of presentation were the same as in Experiment 1.

### DESCRIPTIVE RESULTS

The results regarding the number of target words recalled, as well as the number of stems completed using the words presented in the target list, were tallied for each serial

position, for each presentation modality and word frequency condition. Figures 3a and 3b are graphic representations of the results for the high frequency condition, while Figures 3c and 3d are representations of the results for the low frequency condition. In all conditions the priming measure was adjusted by subtracting the baseline level of priming from the number of stems completed, in order to obtain a pure measure of priming. As in Experiment 1 the baseline level for the target words was obtained using 288 participants, 144 from Experiment 1, and 144 from Experiment 2. The baseline level for low frequency words was 11%, while the baseline for the high frequency words was 26 %.

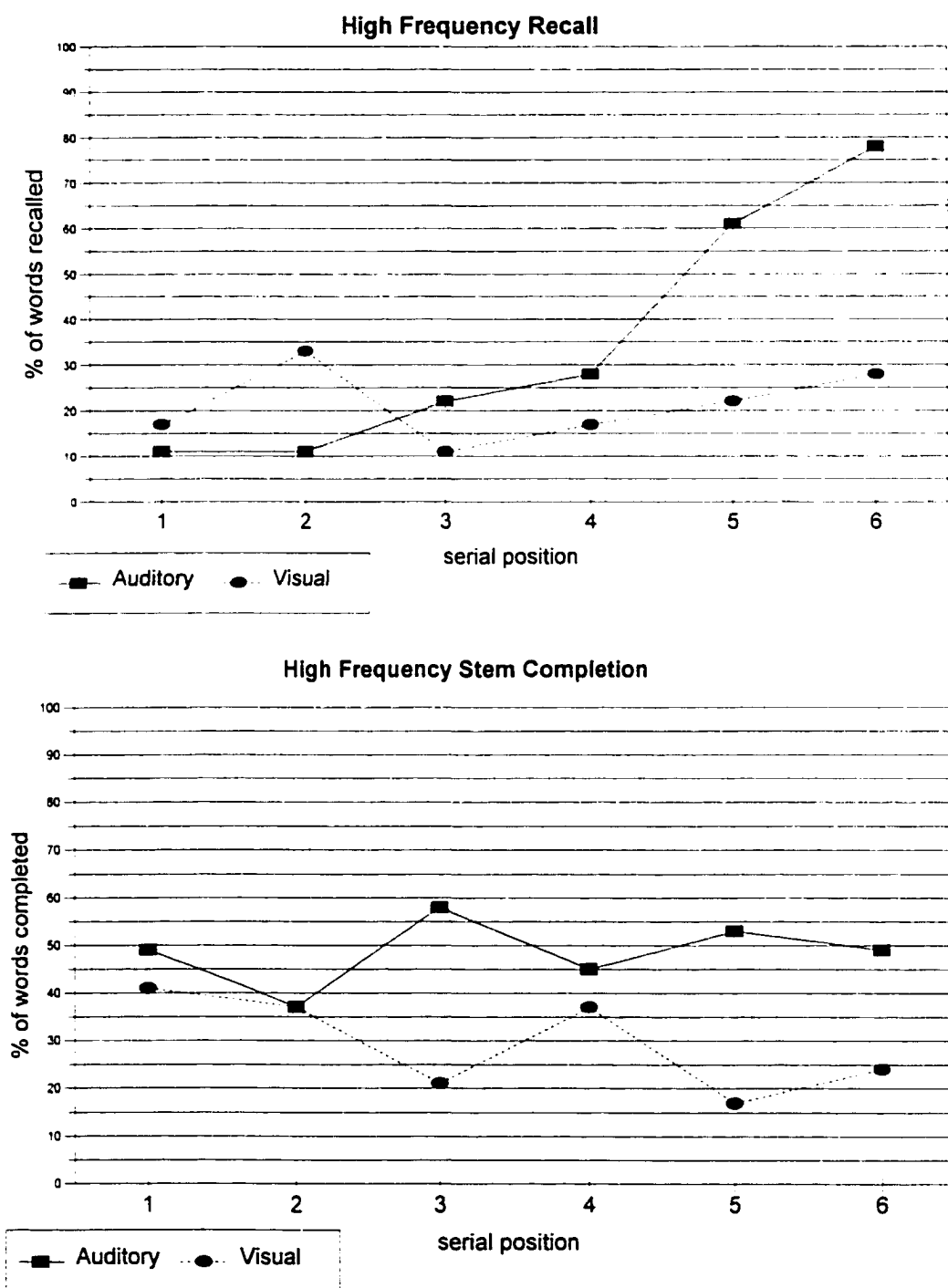
The upper portion of Figures 3a and 3c show the serial position curves for the high frequency recall and low frequency recall conditions. In the auditory recall conditions, the words presented in the last position are recalled better than the words presented in the middle of the list. On the other hand, the serial position curves for the recall visual conditions do not show a large increase in performance at the end of the list. As in Experiment 1, the serial position curves for the stem completion conditions are rather flat lines.

The graphs in the upper portion of Figures 3b and 3d represent the amount of stem completion and recall, in all the conditions, when summed across all the serial positions. As can be seen in these graphs, in all conditions, performance in the auditory condition is better than in the visual condition.

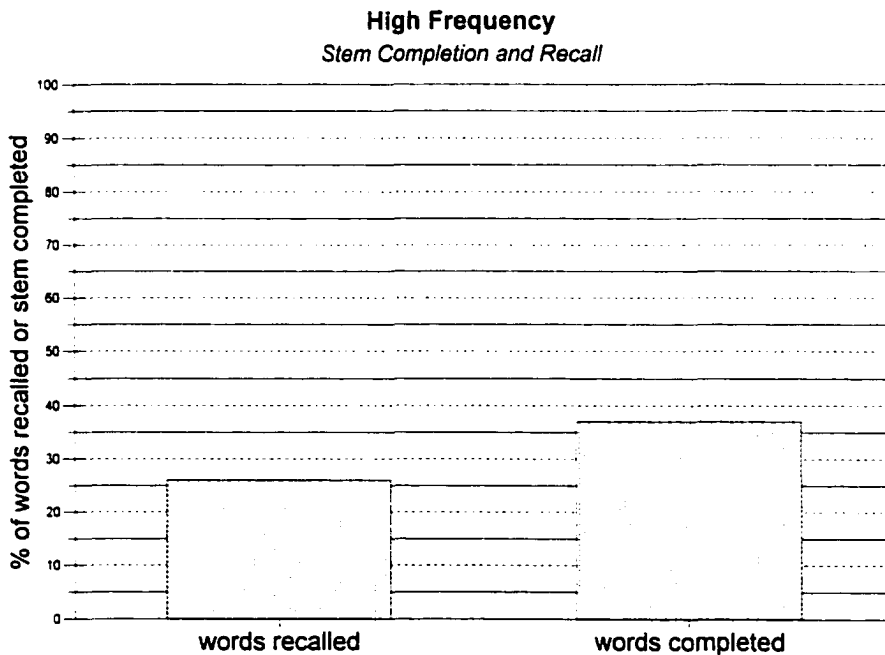
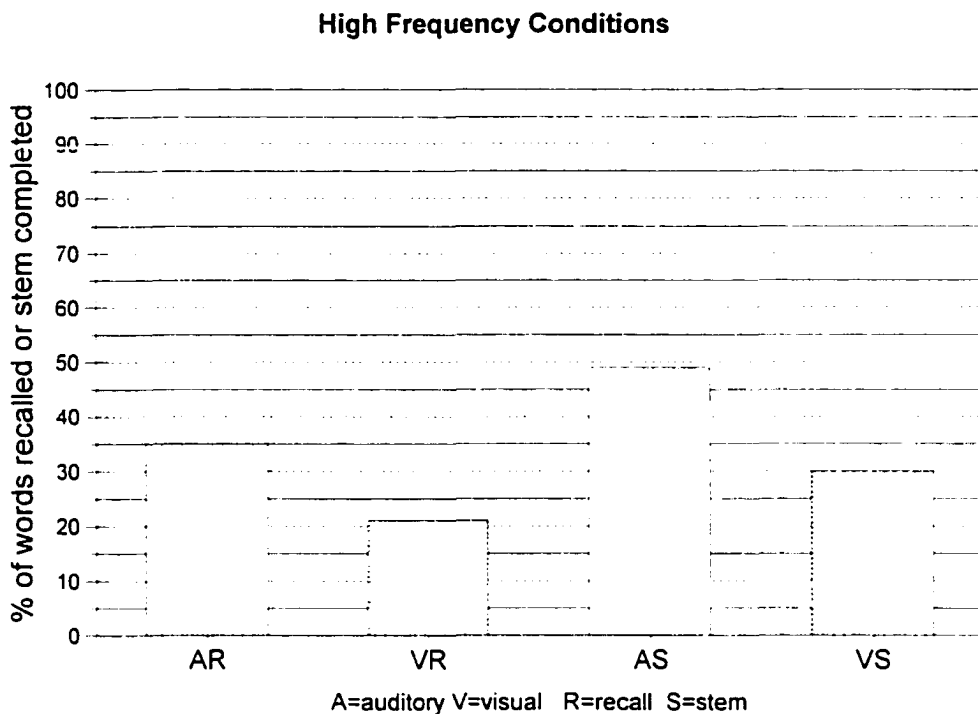
The graphs in the lower portion of Figures 3b and 3c represent the amount of recall and stem completion, when summed across the auditory and visual modalities. For

both, high and low frequency words, priming was better overall than recall. However the difference between recall and priming was much more pronounced in the low frequency than in the high frequency conditions.

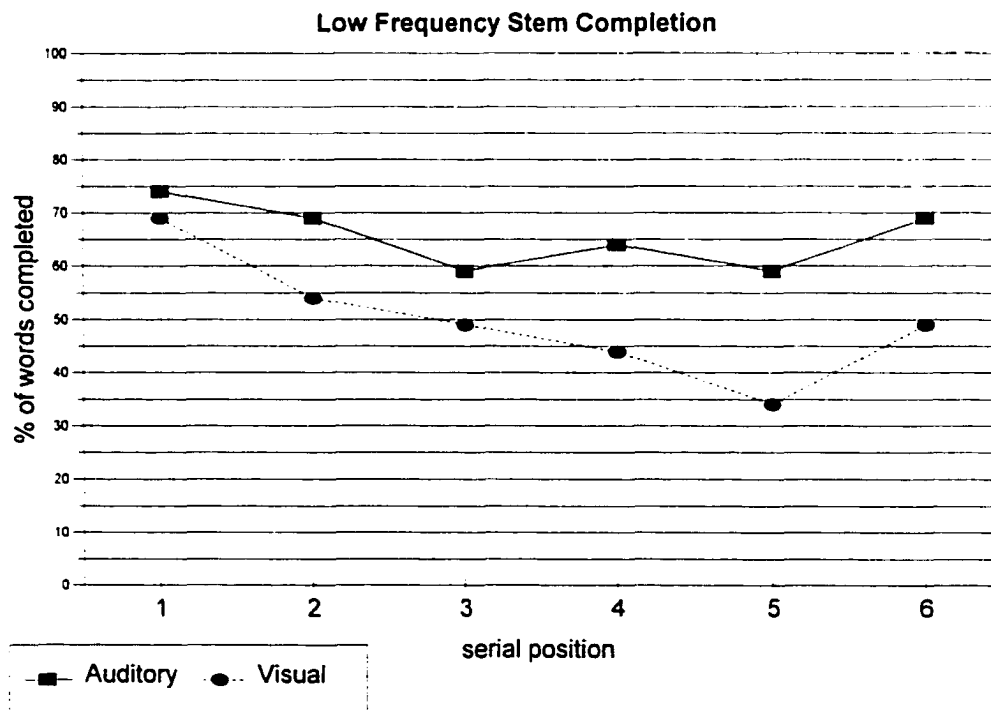
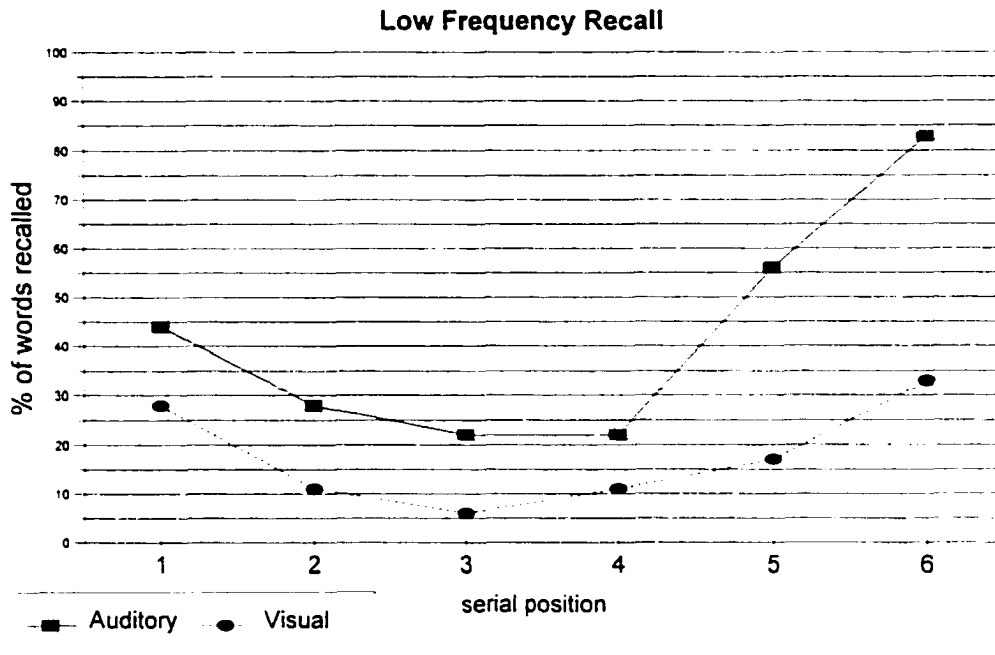
**Figure 3a: Serial Position Results from the High Frequency Conditions in Experiment 2**



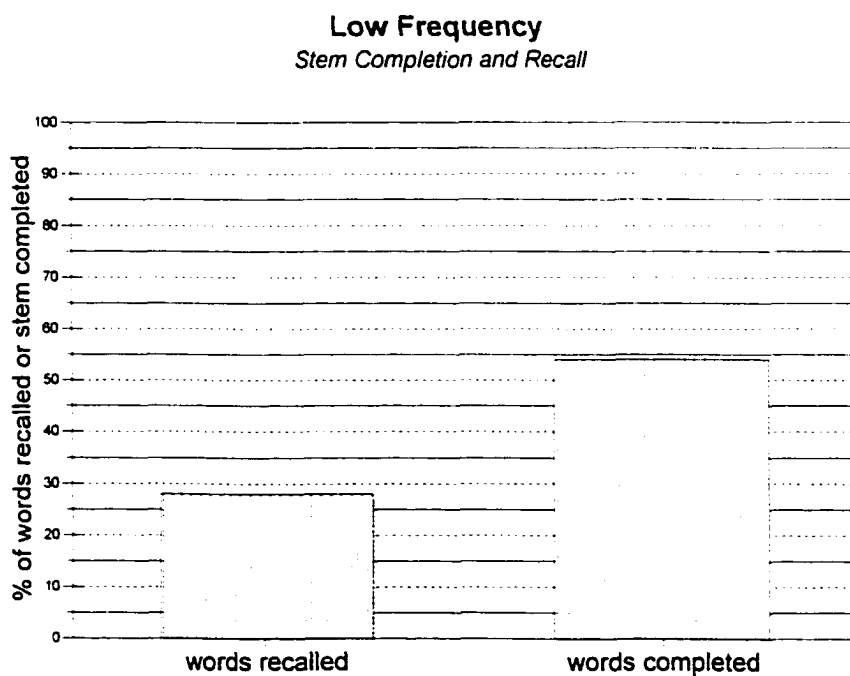
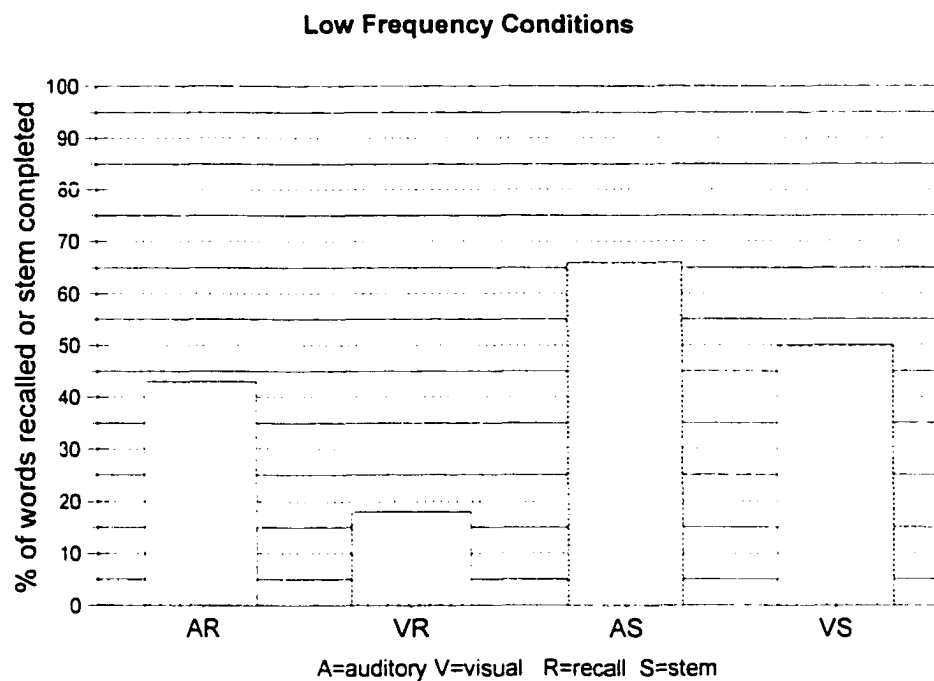
**Figure 3b: Composite Results from the High Frequency Conditions in Experiment 2 (All Serial Positions)**



**Figure 3c: Serial Position Results from the Low Frequency Conditions in Experiment 2**



**Figure 3d: Composite Results from the Low Frequency Conditions in Experiment 2  
(All Serial Positions)**



## METHOD FOR EVALUATING PRIMING AND RECENCY

The method adopted for scoring priming and recency was the same as the one used in Experiment 1.

The results from the eight non-suffix conditions are depicted in Figure 4. In the high frequency condition, the number of participants showing recency appears to be parallel to the number of participants showing priming. As recency decreases from the auditory to the visual condition so does priming. In addition, in both the auditory and visual high frequency conditions, priming is larger than recency. In the low frequency condition, on the other hand, priming and recency do not appear to change in an equal manner, when comparing the auditory and the visual conditions. Recency, in the low frequency condition appears to behave in a similar fashion as it did in the high frequency condition, while priming behaves differently. Priming in the low frequency condition does not change a great deal between the auditory and the visual conditions.

Table 4 shows the frequencies and percentages for each condition of Experiment 2. For each Task (priming and recency), there are two levels of Frequency (high and low), two levels of Modality (auditory and visual) and two levels of Outcome (yes and no). The log-linear analysis performed on the results obtained in Experiment 2 are based on the results from all the conditions, thus, the percentages depicted in Table 2 are based on the total number of participants in Experiment 2, which is 144.

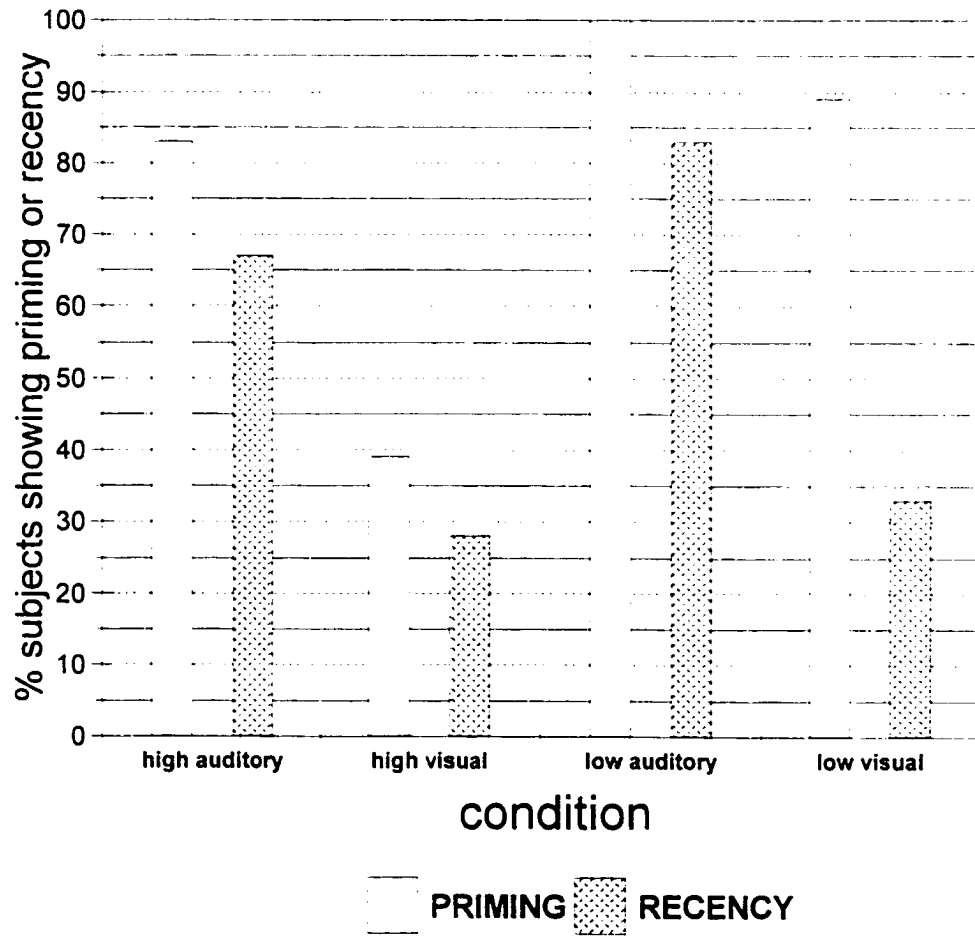
**Figure 4: Priming and Recency in Experiment 2 (Non-Suffix Conditions)**

Table 4:

**Observed Frequencies For the Log-Linear Analysis of Experiment 2**

<u>OUTCOME</u>	<u>MODALITY</u>	<u>FREQUENCY</u>	<u>TASK</u>			
			PRIMING	RECENCY	TOTAL	
Y E S	AUDITORY	HIGH	15 (10.41)	12 (8.33)	27 (18.75)	
		LOW	18 (12.50)	15 (10.41)	33 (22.91)	
		<b>TOTAL</b>	<b>33 (22.91)</b>	<b>27 (18.75)</b>	<b>60 (41.66)</b>	
	VISUAL	HIGH	7 (4.86)	5 (3.47)	12 (8.33)	
		LOW	16 (11.11)	6 (4.16)	22 (15.27)	
		<b>TOTAL</b>	<b>23 (15.97)</b>	<b>11 (7.63)</b>	<b>34 (23.61)</b>	
	<b>SUM OF TOTALS FOR YES</b>			<b>56 (38.88)</b>	<b>38 (26.38)</b>	<b>94 (65.27)</b>
	N O	AUDITORY	HIGH	3 (2.08)	6 (4.16)	9 (6.25)
			LOW	0 (0.00)	3 (2.08)	3 (2.08)
			<b>TOTAL</b>	<b>3 (2.08)</b>	<b>9 (6.25)</b>	<b>12 (8.33)</b>
VISUAL		HIGH	11 (7.63)	13 (9.02)	24 (16.66)	
		LOW	2 (1.38)	12 (8.33)	14 (9.72)	
		<b>TOTAL</b>	<b>13 (9.02)</b>	<b>25 (17.36)</b>	<b>38 (26.38)</b>	
<b>SUM OF TOTALS FOR NO</b>			<b>16 (11.11)</b>	<b>34 (23.61)</b>	<b>50 (34.72)</b>	
<b>GRAND TOTAL</b>					<b>144 (100)</b>	

Note: Percentages are in parenthesis.

## RESULTS AND DISCUSSION

Table 4a is a summary of the results from the logit-model analysis of the data depicted in Table 4. The models used in the analysis are shown in the left portion of Table 4a, together with the  $\chi^2$  value for that model. The right side of Table 4a represents the derived value for each of the three main effects, each of the three first-order interaction effects, and the second-order interaction effect.

As in Experiment 1, the derived effects are obtained by subtracting the  $\chi^2$  value of each model from the previous one. In order to obtain the  $\chi^2$  value of the main effect of Frequency, labeled "FO" in Table 4a, the  $\chi^2$  value of the model "TFM TO FO", which is 31.15, is subtracted from the  $\chi^2$  value of the model "TFM TO", which is 39.71, resulting in a significant main effect of Frequency,  $\chi^2(1) = 8.56$ ,  $p < .05$ . This main effect is due to the difference in the number of participants showing recency and priming combined between the high and the low frequency conditions.

Recency and priming were found in 55 participants in the low frequency conditions, and in 39 participants in the high frequency condition. Priming and recency effects combined were found to occur more often when the words used as stimuli are low frequency rather than high frequency. Table 4 indicates that what leads to this main of Frequency is the difference in priming effects found in the visual high frequency condition, where priming was found in 7 out of 18 participants, and the visual low frequency condition, where priming was observed in 16 out of 18 participants. The Fisher Exact tests

Table 4a

Results of the Logit Model Analysis for Experiment 2

Model	$\chi^2$	df	Effect of	$\chi^2$	df
TFMO	0.0	0			
TFM TFO TMO FMO	0.26	1	TFMO	0.26	1
TFM TFO TMO	0.86	2	FMO	0.60	1
TFM TFO MO	0.93	3	TMO	0.07	1
TFM TO FO MO	6.08	4	TFO*	5.15	1
TFM TO FO	31.15	5	MO*	25.07	1
TFM TO	39.71	6	FO*	8.56	1
TFM O	49.81	7	TO*	10.10	1

=====  
 note:

\* = significant at p.05

Legend:

T = task (priming, recency)

F = frequency (high, low)

M = modality (auditory, visual) O = outcome (yes, no)

shown in Table 4b indicate a significant difference between these two conditions,  $p = .004$ .

As can be seen in Table 4b, in all the conditions, performance in the low frequency condition was better than in the high frequency condition. However, only the test performed between the high and the low frequency visual priming conditions was found to be significant. As previously discussed for Experiment 1, a number of researchers have shown a low frequency advantage in recognition memory (Dennis, 1995; Schulman and Lovelace, 1970), and the similarities between a stem completion task and a recognition task could explain the superior performance in the low frequency conditions. Once again, the low frequency advantage found in the literature would support the results found in this experiment.

The log-linear analysis in Table 4a, also reveals a main effect of Modality,  $\chi^2(1) = 25.07$ ,  $p < .05$ . As may be seen in Table 4, priming and recency effects were seen in 60 participants in the auditory conditions, while 34 participants showed priming and recency in the visual conditions. By observing the data depicted in Table 4 in more detail, it is possible to see that there was an auditory advantage in all the conditions. Table 4c is a representation of the four Fisher Exact tests performed in the four auditory and visual conditions. The Fisher Exact test performed on the data from the high frequency priming condition was significant,  $p = .015$ . The tests performed on the data for the recency low frequency condition,  $p = .001$ , and recency high frequency conditions,  $p = .043$ , were also significant. On the other hand, the analysis of the data in the priming low frequency condition was not significant,  $p = .485$ . These results are supported by the literature on

recency, whereby auditory presentation leads to a greater recency than visual presentation, while presentation modality does not appear to produce analogous effects on priming. The Fisher Exact tests performed in the two recency conditions were both significant, while for priming only the test for the high frequency condition was significant. These results are not as powerful as the results obtained in Experiment 1 in indicating a difference in the effect of modality on priming and recency. However, they nevertheless suggest that modality of presentation has a greater effect on recency than on priming.

Table 4a also shows a significant main effect of Task, suggesting that priming and recency are significantly different from each other, when summed across Modality and Frequency,  $\chi^2(1) = 10.10, p < .05$ . As may be seen in Table 4, summing across all the conditions, 56 participants showed priming effects, while 38 showed recency. The main effect of Task is therefore produced by the greater overall amount of priming, when compared to recency. Table 4 shows that priming was observed more often than recency in all the conditions of Experiment 2. The four Fisher Exact tests performed on priming and recency in Experiment 2 are depicted in Table 4d, and indicate that the only significant difference was found in the visual low frequency condition,  $p = .001$ . No significant difference between priming and recency was found in the auditory high frequency condition,  $p = .443$ , in the auditory low frequency condition,  $p = .228$ , and in the visual high frequency condition,  $p = .724$ . In the visual low frequency condition, the significant difference between priming and recency is driven by the lower amount of recency, as compared to the amount of priming, found in the same condition. In the visual low

frequency condition, 16 participants showed priming, while only 6 showed recency. On the other hand, in the auditory low frequency condition, 18 participants showed priming, and 15 showed recency. Thus, there was a decrease in recency in the visual condition, when comparing it to the auditory condition, while there was little difference in the amount of priming found in the different modalities. Once again, the data reflects the expected auditory superiority effect that is typical of the literature on recency, while priming does not appear to be affected by presentation modality.

As previously discussed for Experiment 1, in order to obtain a positive outcome for the priming and the recency measures, the level of priming or recency had to exceed criterion levels. Since both methods used to establish criterion are consistent with the definitions of priming and recency effects, the significant difference suggested by the main effect of Task may be used as an indication that the priming and recency effects may be part of different processes. However, an even stronger argument in support of a dissociation can be raised by the presence of a significant interaction effect.

Table 4b

**Results of Fisher Exact Tests Performed Between the High and Low Frequency  
Conditions of Experiment 2**

## Priming Auditory Condition

	Outcome Yes	Outcome No
High Frequency	15	3
Low Frequency	18	0

Fisher Exact

 $p = .228$ 

## Recency Auditory Condition

	Outcome Yes	Outcome No
High Frequency	12	6
Low Frequency	15	3

Fisher Exact

 $p = .443$ 

## Priming Visual Condition

	Outcome Yes	Outcome No
High Frequency	7	11
Low Frequency	16	2

Fisher Exact

 $p = .004$ 

## Recency Visual Condition

	Outcome Yes	Outcome No
High Frequency	5	13
Low Frequency	6	12

Fisher Exact

 $p = 1$

Table 4c

**Results of Fisher Exact Tests Performed Between the Auditory and Visual  
Conditions of Experiment 2**

## Priming High Frequency Condition

	Outcome Yes	Outcome No	
Auditory	15	3	Fisher Exact $p = .015$
Visual	7	11	

## Priming Low Frequency Condition

	Outcome Yes	Outcome No	
Auditory	18	0	Fisher Exact $p = .485$
Visual	16	2	

## Recency High Frequency Condition

	Outcome Yes	Outcome No	
Auditory	12	6	Fisher Exact $p = .043$
Visual	5	13	

## Recency Low Frequency Condition

	Outcome Yes	Outcome No	
Auditory	16	2	Fisher Exact $p = .001$
Visual	6	12	

Table 4d

**Results of Fisher Exact Tests Performed Between the Priming and Recency Conditions of Experiment 2**

Auditory High Frequency Condition

	Outcome Yes	Outcome No
Priming	15	3
Recency	12	6

Fisher Exact

p= .443

Auditory Low Frequency Condition

	Outcome Yes	Outcome No
Priming	18	0
Recency	15	3

Fisher Exact

p= .228

Visual High Frequency Condition

	Outcome Yes	Outcome No
Priming	7	11
Recency	5	13

Fisher Exact

p= .724

Visual Low Frequency Condition

	Outcome Yes	Outcome No
Priming	16	2
Recency	6	12

Fisher Exact

p= .001

Providing stronger evidence of a dissociation between priming and recency, the log-linear analysis in Table 4 shows a significant interaction of Task X Frequency,  $\chi^2(1) = 5.15, p < .05$ . The significant interaction suggests that the degree of priming and recency are different when compared for the high and the low frequency conditions. Figure 4a suggests that this interaction is due to the strong priming effect produced by the low frequency conditions, while the low frequency stimuli do not lead to a significant increase in recency. In addition, both the levels of priming and recency found in the high frequency conditions are much lower. As may be seen in Table 4, of the 36 participants in the low frequency priming conditions, 34 showed priming, while of the 36 participants in the low frequency recency conditions only 21 showed recency. Furthermore, in the high frequency conditions, 22 participants showed priming, and 17 showed recency. Table 4e is a representation of the two Fisher Exact tests that resulted from the comparison of priming and recency in the high and low frequency conditions. Priming and recency were significantly different in the low frequency conditions,  $p = .0005$ , while there was no significant difference between priming and recency in the high frequency condition,  $p = .344$ .

**Figure 4a: Experiment 2: Interaction of Task by Frequency**

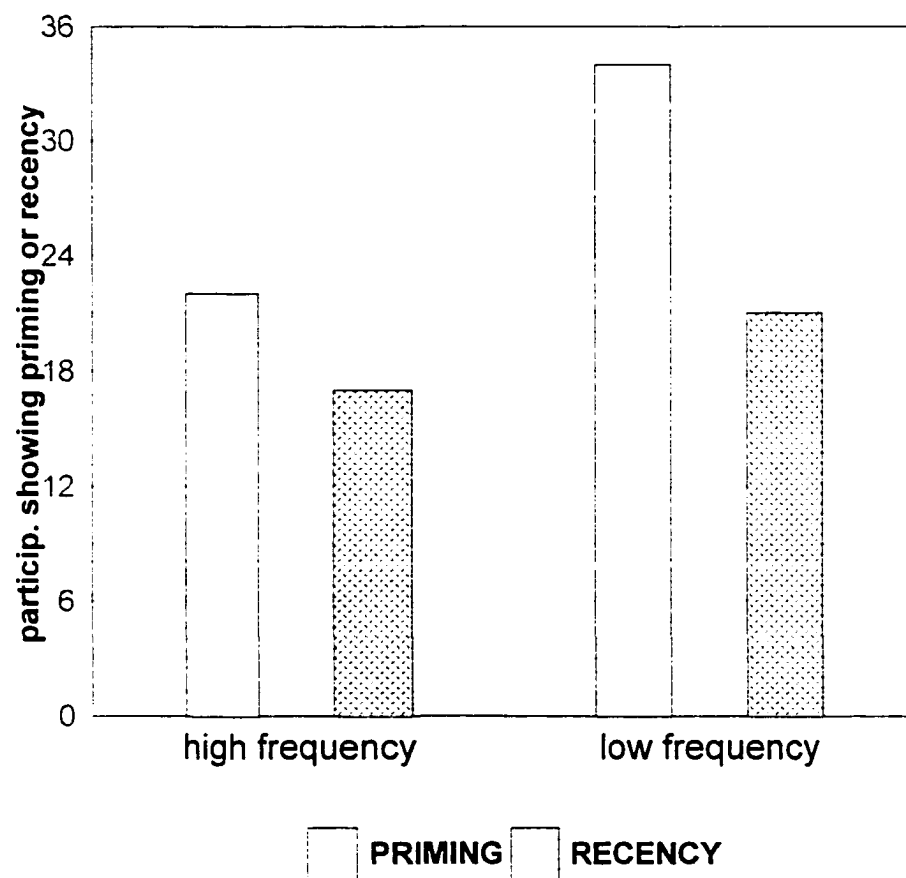


Table 4c

**Results of Fisher Exact Tests Performed Between Priming and Recency in the high and the low frequency Conditions**

## High Frequency Condition

	Outcome Yes	Outcome No	
Priming	22	14	Fisher Exact p= .344
Recency	17	19	

## Low Frequency Condition

	Outcome Yes	Outcome No	
Priming	34	2	Fisher Exact p= .0005
Recency	21	15	

The significant interaction between Task and Frequency may be related to the observation that, when low frequency words are used as stimuli, a greater amount of priming is produced than when high frequency words are used as stimuli. On the other hand, recency does not appear to be affected by word frequency. As previously discussed for the main effect of Frequency, a number of researchers have provided evidence for a low frequency advantage in word recognition (Dennis, 1995; Schulman and Lovelace, 1970). It is possible that the stem completion task, used to measure priming, may be similar to a recognition task. The demands of the two tasks are similar, because in order to complete a stem completion task, the participants have to “recognize” a stem as belonging to a word. Thus, the low frequency advantage found in the stem completion task, may be explained by its similarity to a recognition task.

Consistent with the results found in this experiment are the results reported in an experiment by Kinoshita (1995). This research reports a low frequency advantage in a priming task. However, the priming task used by Kinoshita was a lexical decision task, as opposed to the stem completion task used in this experiment. Interestingly, lexical decision tasks also share some common elements with a recognition task. In a lexical decision task, participants have to determine as quickly as possible if a string of letters forms a complete word or not. Thus, in the case when the string of letters produces a word, the participants have to “recognize” that word. Thus it may be a particular and similar or related process, used for recognition tasks, stem completion tasks and lexical decision tasks, that leads, in all these situations, to a low frequency advantage.

More relevant to the aim of this experiment, priming and recency effects were found to respond differently to changes in the frequency of the stimuli. Low frequency stimuli led to a greater priming effect than high frequency stimuli, while high and low frequency stimuli led to similar levels of recency. If the priming and recency effects were parts of the same implicit memory process, the frequency of the stimuli should affect them in the same way. Thus, the Baddeley and Hitch (1993) hypothesis that priming and recency effects are parts of the same implicit memory process is contradicted by the results of Experiment 2. These results show evidence that indicates a dissociation between priming and recency, suggesting that the two effects are not parts of the same implicit memory process.

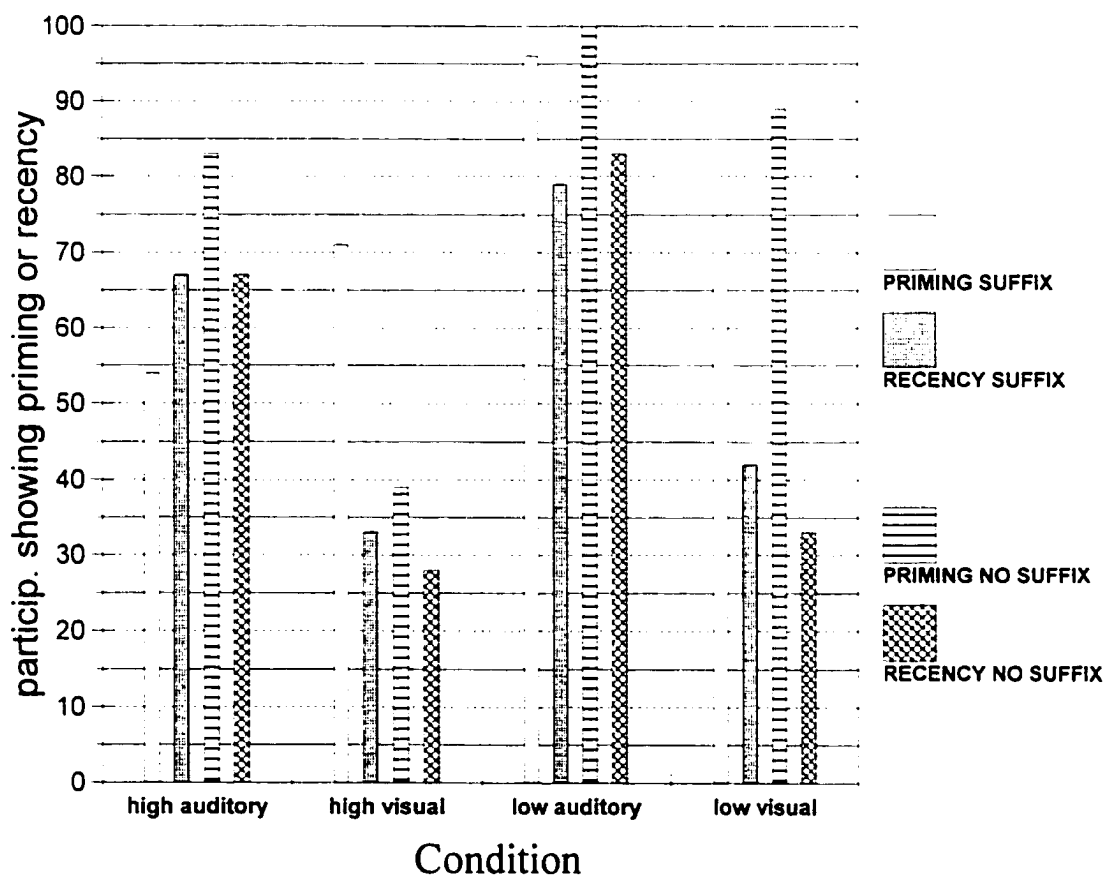
## COMBINED ANALYSIS OF EXPERIMENTS 1 AND 2

The data from Experiment 1 and 2 were compared, and Figure 5 is a representation of the comparison. The main difference between the two experiments is that, in Experiment 1 a digit was presented at the end of the target list, potentially acting as a suffix, while in Experiment 2, the target list ended with a word. The first question that could be answered by analyzing the results from the two Experiments together, would be to determine if the suffix used in Experiment 1 produces an effect. The descriptive data in Figure 5 indicates that the amount of recency is very similar for the suffix and non-suffix conditions, suggesting, as expected, that the suffix used in Experiment 1 did not lead to a decrease in recency.

In addition, Figure 5 shows that the greatest amount of recency appears to be produced in the auditory conditions, of both high and low frequency conditions. That is, evidence that the modality effect was present in both Experiments. Furthermore, but to a lesser degree, recency appears to be more pronounced in the low frequency as opposed to the high frequency conditions. Priming, on the other hand, appears to be more affected by word frequency, with low frequency stimuli leading to greater priming. When priming and recency are compared in the different conditions, the largest difference between the two is found in the low frequency visual condition. In this condition, priming is greater than recency both in the suffix as well as the non-suffix condition.

In general, the descriptive results presented in Figure 5, appear to provide further evidence that recency is more sensitive to changes in modality, while priming is more

**Figure 5: Priming and Recency in Experiments 1 and 2**



sensitive to changes in word frequency, with low frequency words leading to greater priming than high frequency words.

Table 5 shows the frequencies and percentages for each condition of Experiments 1 and 2. For each Task (priming and recency), there are two levels of Frequency (high and low), two levels of Modality (auditory and visual). For clarity, Table 5 only depicts “yes outcomes” in the two Experiments, that is instances where the participants showed priming or recency. The number of “no outcomes” can easily be obtained by the difference between “yes outcomes” and the total number of participants in that condition. The number of participants in each condition of Experiment 1 was 24, and in Experiment 2 was 18. The percentages depicted in Table 2 are based on the number of participants in each Experiment, 192 in Experiment 1 and 144 in Experiment 2.

The log-linear analysis, as well as the Fisher Exact test, can be performed over groups having different number of participants, and therefore this aspect did not create a problem for the analyses. The only minor problem produced by the different number of subjects in the two experiments is that, in some of the Fisher Exact tests, when the results of Experiment 1 and 2 are combined, the results from Experiment 1 are weighted slightly more than the results from Experiment 2. The population in Experiment 1 is 57.1 % of the total number of participants in Experiments 1 and 2 combined, while the population in Experiment 2 is 42.8 % of the total.

Table 5a is a summary of the results from the logit-model analysis of the data from Experiments 1 and 2. When comparing this analysis to the ones performed for

Experiments 1 and 2, it is evident that this analysis contains an additional factor, Suffix. Experiments 1 and 2 were identical, except for the presentation of the suffix. Thus, for the purpose of the log-linear analysis, the two Experiments could be regarded as different conditions of the same experiment, and Suffix was regarded as an additional variable, with two levels, suffix condition and non-suffix condition.

The models used in the analysis are shown in the left portion of Table 5a, together with the  $\chi^2$  value for that model. The right side of Table 3 represents the derived value for each of the four main effects, the six two-way interaction effects, the four three-way interaction effects, and the four-way interaction effect. As described for Experiments 1 and 2, the derived effects are obtained by subtracting the  $\chi^2$  value of each model from the previous one.

The log-linear analysis in Table 5a indicates that there is no main effect of Suffix. This non-significant main effect indicates that there was no significant difference between the suffix and the non-suffix conditions. These results were expected, since the suffix used was a digit, while the targets were words. As previously discussed, Gardiner and Gregg (1979), found no suffix effect when the suffix was provided by instructing the participants to count backwards, before and after each to be remembered item, including the last one. In addition to that, Watkins and Peynircioglu (1983), when presenting words of three different categories within the same list, obtained three recency effects, so that the last word presented did not act as a suffix for the words from different categories presented before it. Thus, there is evidence in the literature that supports the results found in this

experiment, that when information from different categories are presented within the same list, the item presented last does not reduce recency in the other category.

Table 5a shows a significant main effect of Frequency,  $\chi^2(1) = 14.2, p < .05$ . This main effect is due to the difference in the number of participants showing recency and priming combined, for the high and the low frequency conditions, in Experiments 1 and 2. Of the 168 participants in each group, 93 showed priming or recency in the high frequency conditions, and 125 in the low frequency conditions. Thus, the presentation of low frequency words as stimuli, led to a greater occurrence of the priming and recency effects than when the stimuli presented were high frequency words. Table 5 indicates that, for every condition, in each experiment, priming and recency occur more often in the low frequency condition than in the high frequency condition. In particular, the difference between the high and low frequency conditions appears to be greater for priming than it is for recency. The four Fisher Exact tests depicted in Table 5b confirm this hypothesis. The Fisher Exact tests for the two priming conditions are significant, while the tests for the two recency conditions are not. In the priming auditory conditions, in Experiments 1 and 2 combined, 28 participants showed priming in the high frequency conditions, and 41 showed priming in the low frequency conditions. This resulted in a significant difference, indicated by the Fisher Exact test,  $p = .0003$ . Similarly, in the priming visual conditions, 24 participants showed priming in the high frequency conditions, and 34 showed priming in the low frequency conditions, resulting in a significant Fisher Exact,  $p = .032$ .

As in Experiments 1 and 2, these combined analyses indicate that recency only

appears to be marginally affected by the frequency of the stimuli, while the frequency of the stimuli has a great effect on the occurrence of priming. In particular, low frequency words lead to greater priming than high frequency words. This low frequency advantage for priming may be explained by the similarities between the stem completion task, used to measure priming, and a recognition task. In order to perform a stem completion task, participants may employ a strategy whereby they "recognize" the stem as belonging to a particular word. This similarity between the stem completion task and a recognition task would explain the low frequency advantage found for priming, since a number of researchers have found a low frequency advantage for recognition memory (Dennis, 1995; Schulman and Lovelace, 1970). Thus, these results once again support the hypothesis of a dissociation between priming and recency, since they were affected differently by the frequency of the stimuli.

Table 5

**Observed Frequencies For the Log-Linear Analysis of Experiments 1 and 2****EXPERIMENT 1**

OUTCOME	MODALITY	FREQUENCY	TASK		
			PRIMING	RECENCY	TOTAL
Y E S	AUDITORY	HIGH	13 ( 6.77)	16 ( 8.33)	29 (15.10)
		LOW	23 (11.98)	19 ( 9.89)	42 (21.87)
		<b>TOTAL</b>	<b>36 (18.75)</b>	<b>35 (18.23)</b>	<b>71 (36.98)</b>
	VISUAL	HIGH	17 ( 8.85)	8 (4.16)	25 (13.02)
		LOW	18 ( 9.37)	10 (5.20)	28 (14.58)
		<b>TOTAL</b>	<b>35 (18.23)</b>	<b>18 (9.37)</b>	<b>53 (27.60)</b>
	<b>SUM OF TOTALS</b>		<b>71 (36.98)</b>	<b>53 (27.60)</b>	<b>124 (64.58)</b>

**EXPERIMENT 2**

Y E S	AUDITORY	HIGH	15 (10.41)	12 ( 8.33)	27 (18.75)
		LOW	18 (12.50)	15 (10.41)	33 (22.91)
		<b>TOTAL</b>	<b>33 (22.91)</b>	<b>27 (18.75)</b>	<b>60 (41.66)</b>
	VISUAL	HIGH	7 ( 4.86)	5 ( 3.47)	12 ( 8.33)
		LOW	16 (11.11)	6 ( 4.16)	22 (15.27)
		<b>TOTAL</b>	<b>23 (15.97)</b>	<b>11 ( 7.63)</b>	<b>34 (23.61)</b>
	<b>SUM OF TOTALS</b>		<b>56 (38.88)</b>	<b>38 (26.38)</b>	<b>94 (65.27)</b>

Note: Percentages are in parenthesis.

Table 5a

Results of the Log-Linear Analysis of Experiments 1 and 2

Model	$\chi^2$	df	Effect of	$\chi^2$	df
TFMSO	0.0	0			
TFMS TFMO TFSS TMSO FMSO	0.0	1	TFMSO	0.0	1
TFMS TFMO TFSS TMSO	0.1	2	FMSO	0.1	1
TFMS TFMO TFSS MSO	4.0	3	TMSO*	3.9	1
TFMS TFMO TSO FSO MSO	5.6	4	TFSS	1.6	1
TFMS TFO TMO TSO FMO FSO MSO	7.2	5	TFMO	1.5	1
TFMS TFO TMO TSO FMO FSO	11.7	6	MSO*	4.5	1
TFMS TFO TMO TSO FMO	12.3	7	FSO	0.6	1
TFMS TFO TMO TSO	14.7	8	FMO	2.4	1
TFMS TFO TMO SO	15.2	9	TSO	0.5	1
TFMS TFO MO SO	18.1	10	TMO	2.9	1
TFMS TO FO MO SO	23.9	11	TFO*	5.7	1
TFMS TO FO MO	23.9	12	SO	0.0	1
TFMS TO FO	52.4	13	MO*	28.5	1
TFMS TO	66.6	14	FO*	14.2	1
TFMS O	83.8	15	TO*	17.1	1

note:

\* = significant at p.05

Legend:

T = task (priming, recency)

F = frequency (high, low)

M = modality (auditory, visual)

O = outcome (yes, no)

S = suffix (with suffix, without suffix)

The log-linear analysis in Table 5a shows a main effect of Modality for Experiments 1 and 2 combined,  $\chi^2(1)= 28.5$ ,  $p<.05$ . A greater amount of priming and recency was observed in the auditory conditions, suggesting an auditory superiority effect. The auditory conditions led to priming and recency in 131 participants, while the visual conditions led to priming and recency in 87 participants. Table 5 shows that, in all conditions, the auditory presentation led to better performance than the visual presentation. As expected, the greatest difference between the auditory and visual presentation occurred in the recency conditions. As may be seen in Table 5c, recency was seen in 35 participants in the low frequency auditory conditions, and in 16 participants in the low frequency visual conditions, resulting in a significant Fisher Exact test,  $p= .00004$ . Similarly, recency was observed in 28 participants in the auditory high frequency conditions, and in 13 participants in the high frequency visual conditions, leading to a significant Fisher Exact test,  $p= .002$ . A significant difference was also found in the amount of priming in the auditory and visual low frequency condition. However the level of significance of the Fisher Exact test,  $p= .029$ , was not as strong as for the recency conditions. The level of priming found in the auditory and visual high frequency conditions did not differ significantly. As shown in Experiments 1 and 2, these combined results indicate a dissociation between priming and recency. Auditory superiority is a well established phenomenon in the literature on recency, while auditory presentation of stimuli is not known to produce greater priming than visual presentation.

The log-linear analysis in Table 5a also reveals a significant main effect of Task,

indicating that priming and recency are significantly different from each other, when summed across Modality and Frequency, in Experiments 1 and 2 combined,  $\chi^2(1) = 17.1$ ,  $p < .05$ . As may be seen in Table 5, 127 participants showed priming effects, while 91 showed recency. The main effect of Task is therefore due to the greater overall amount of priming, when compared to recency. Table 5d shows that the greatest difference between the priming and recency effects are found in the auditory and visual low frequency conditions, and in the high frequency visual conditions. The four Fisher Exact tests, depicted in Table 5d, indicate that there is a significant difference in the auditory low frequency conditions,  $p = .029$ , in the visual low frequency conditions,  $p = .0001$ , and in the visual high frequency conditions,  $p = .027$ , while no significant difference between priming and recency was found in the auditory high frequency conditions. In the low frequency conditions, the significant difference is due to a greater amount of priming. As previously discussed, low frequency stimuli produce a greater amount of priming, while recency is not affected by it. The difference between priming and recency in the low frequency auditory conditions is not as large as the one found in the low frequency visual conditions, due to the greater amount of recency. This greater amount of recency may be explained by the auditory presentation leading to greater recency. The significant difference between priming and recency in the visual high frequency conditions appears to be due to the low amount of recency produced by the visual presentation of the stimuli, while priming is not reduced as much by the modality of presentation. Finally, a lack of differences in the auditory high frequency conditions appear to be due to, on the one hand the increased

amount of recency found because of the auditory presentation, and on the other hand the decreased amount of priming because of the high frequency words presented. Again, these results point in the direction of a dissociation between priming and recency, since the two appear to be affected differently by different variables.

Table 5b

**Results of Fisher Exact Tests Performed Between the High and Low Frequency  
Conditions of Experiments 1 and 2**

## Priming Auditory Condition

	Outcome Yes	Outcome No
High Frequency	28	14
Low Frequency	41	1

Fisher Exact

p= .0003

## Recency Auditory Condition

	Outcome Yes	Outcome No
High Frequency	28	14
Low Frequency	34	8

Fisher Exact

p= .214

## Priming Visual Condition

	Outcome Yes	Outcome No
High Frequency	24	18
Low Frequency	34	8

Fisher Exact

p= .032

## Recency Visual Condition

	Outcome Yes	Outcome No
High Frequency	13	29
Low Frequency	16	26

Fisher Exact

p= .646

Table 5c

**Results of Fisher Exact Tests Performed Between the Auditory and Visual  
Conditions of Experiments 1 and 2**

Priming High Frequency Condition

	Outcome Yes	Outcome No
Auditory	28	14
Visual	24	18

Fisher Exact

p= .500

Priming Low Frequency Condition

	Outcome Yes	Outcome No
Auditory	41	1
Visual	34	8

Fisher Exact

p= .029

Recency High Frequency Condition

	Outcome Yes	Outcome No
Auditory	28	14
Visual	13	29

Fisher Exact

p= .002

Recency Low Frequency Condition

	Outcome Yes	Outcome No
Auditory	35	7
Visual	16	26

Fisher Exact

p= .00004

Table 5d

**Results of Fisher Exact Tests Performed Between the Priming and Recency Conditions of Experiments 1 and 2**

## Auditory High Frequency Condition

	Outcome Yes	Outcome No
Priming	28	14
Recency	28	14

Fisher Exact

 $p = 1$ 

## Auditory Low Frequency Condition

	Outcome Yes	Outcome No
Priming	41	1
Recency	34	8

Fisher Exact

 $p = .029$ 

## Visual High Frequency Condition

	Outcome Yes	Outcome No
Priming	24	18
Recency	13	29

Fisher Exact

 $p = .027$ 

## Visual Low Frequency Condition

	Outcome Yes	Outcome No
Priming	34	8
Recency	16	26

Fisher Exact

 $p = .0001$

The log-linear analysis in Table 5a shows a significant interaction of Task by Frequency,  $\chi^2(1) = 5.7$ ,  $p < .05$ . In the high frequency conditions, 52 participants showed priming and 51 showed recency, while in the low frequency conditions, 75 participants showed priming and 50 showed recency. Both priming and recency effects occurred less often in the high frequency conditions, as compared to the low frequency conditions. In addition, in all conditions, priming was greater than recency. As may be seen in Table 5e, the Fisher Exact tests performed on the data indicate a significant difference between priming and recency in the high frequency conditions,  $p = .0019$ , as well as in the low frequency conditions,  $p = .00001$ . In addition, while there was a significant difference between priming in the low frequency conditions and recency in the high frequency conditions,  $p < .000001$ , there was no significant difference between priming in the high frequency conditions and recency in the low frequency conditions,  $p = .874$ . The data used for this analysis were summed over the auditory and visual modalities of presentation. When the modality of presentation is controlled for, as it was done in Table 5b, it is possible to see that low frequency stimuli lead to greater priming than high frequency stimuli, while the frequency of the stimuli does not have a great effect on recency. Therefore, the interaction of Task X Frequency can be explained by the greater overall level of priming, as compared to recency, as well as by priming being more sensitive to changes in the frequency of the stimuli than recency. These results give further support to the idea that priming and recency are parts of different memory processes.

Furthermore, the analysis in Table 5 shows an interaction effect of Modality X

Suffix. Even though this analysis does not relate to similarities or differences between priming and recency, since in this analysis the two are added together, it may nevertheless be worth exploring in more detail. Overall, priming and recency effects were stronger in auditory as opposed to visual conditions, as suggested previously by the main effect of Modality. As may be seen in Table 5, in the auditory suffix conditions, 36.98 % of the participants showed priming and recency, while in the suffix visual conditions 27.60 % of the participants showed priming and recency. Similarly, priming and recency was observed in 41.66 % of the participants in the non-suffix auditory conditions, and in 23.61 % of the participants in the non-suffix visual conditions. These data also revealed that priming and recency in the auditory conditions were observed more frequently in the non-suffix than in the suffix condition. On the other hand, in the visual conditions the opposite occurred, with priming and recency resulting more frequently in the suffix than in the non-suffix conditions.

Table 5f illustrates the results of four Fisher Exact tests, performed on the data from the Modality X Suffix interaction. For both, the suffix and the non-suffix conditions, there was a significant difference in the amount of priming and recency observed in the auditory and visual conditions. Even though a greater proportion of both priming and recency was found in the non-suffix auditory, as compared to the suffix auditory condition, suggesting that a suffix effect may be involved, the Fisher Exact test performed did not indicate a significant difference to be present,  $p = .188$ . Similarly, there was no significant difference for the suffix and non-suffix visual conditions,  $p = .35$ .

Table 5e

**Results of Fisher Exact Tests Performed on the Data from the Interaction of Task X  
Frequency of Experiments 1 and 2**

## High Frequency Conditions

	Outcome Yes	Outcome No
Priming	52	32
Recency	31	53

Fisher Exact

 $p=.0019$ 

## Low Frequency Condition

	Outcome Yes	Outcome No
Priming	75	9
Recency	50	34

Fisher Exact

 $p= .00001$ 

## Priming High Frequency and Recency Low Frequency

	Outcome Yes	Outcome No
Priming High Freq.	52	32
Recency Low Freq.	50	34

Fisher Exact

 $p= .874$ 

## Priming Low Frequency and Recency High Frequency

	Outcome Yes	Outcome No
Priming Low Freq.	75	9
Recency High Freq.	50	34

Fisher Exact

 $p< .00001$

Table 5f

**Results of Fisher Exact Tests Performed on the Data from the Interaction of  
Modality X Suffix of Experiments 1 and 2**

## Suffix Conditions

	Outcome Yes	Outcome No
Auditory	71	25
Visual	53	43

Fisher Exact  
 $p=.010$

## Non-suffix Conditions

	Outcome Yes	Outcome No
Auditory	60	12
Visual	34	38

Fisher Exact  
 $p< .00001$

## Auditory Conditions

	Outcome Yes	Outcome No
Suffix	71	25
Non-suffix	60	12

Fisher Exact  
 $p= .188$

## Visual Conditions

	Outcome Yes	Outcome No
Suffix	53	43
Non-suffix	34	38

Fisher Exact  
 $p< .35$

A 3 way interaction, of Task X Modality X Suffix, was also revealed in Table 5. Figure 5a is a graphic representation of this interaction. The most striking aspect of Figure 5a is the difference in recency between the visual and the auditory conditions. As may be seen in Table 5, in the suffix auditory condition 18.23 % of the participants showed recency, while in the suffix visual condition recency was found in 9.37 % of the participants. Similarly, recency was found in 18.75 % of the participants in the non-suffix auditory condition, and in 7.63 % of the participants in the non-suffix visual condition. These results also show that the difference between recency in the suffix and non-suffix conditions is minimal.

Four Fisher Exact tests were performed between the suffix and non-suffix conditions, in the two Tasks and the two Modalities, and none was found significant. In the recency auditory conditions  $p= 1$ , in the recency visual conditions  $p= .64$ , in the priming auditory conditions  $p= .081$ , and in the priming visual conditions  $p= .475$ . These results confirmed that there was no difference in the levels of priming and recency for Experiments 1 and 2.

Table 5g depicts the four Fisher Exact tests performed for the auditory and visual conditions for Task and Suffix. As expected, recency was found to be significantly different between the auditory and visual conditions of both suffix and non-suffix conditions. The level of priming found for the auditory, and visual conditions of the suffix condition were not significantly different,  $p= 1$ , while in the non-suffix condition there was a significant difference,  $p= .0009$ . An examination of Table 5 reveals a very low level of

priming in the non-suffix visual high frequency condition. It appears that the reason for the significant difference in priming for the auditory and visual conditions of the non-suffix conditions, may not be due to a decrease in priming caused by the visual presentation, but rather by a low level of priming caused by the presentation of high frequency stimuli. Thus, recency appears to be affected by modality of presentation more so than priming, suggesting a dissociation between priming and recency.

Table 5h depicts the four Fisher Exact tests performed for priming and recency in the two Suffix and the two Modality conditions. Priming and recency were found to be significantly different in the two visual conditions, in the suffix visual condition  $p = .0009$ , and in the non-suffix visual condition  $p = .0089$ . On the other hand, there was no difference between priming and recency in the two auditory conditions, in the suffix auditory condition  $p = 1$ , and in the non-suffix auditory condition  $p = .111$ . The significant differences found between priming and recency in the visual conditions appear to be due to a reduction in the level of recency in the visual modality, while priming does not decrease with visual presentation. Again, a dissociation between priming and recency is suggested by these results.

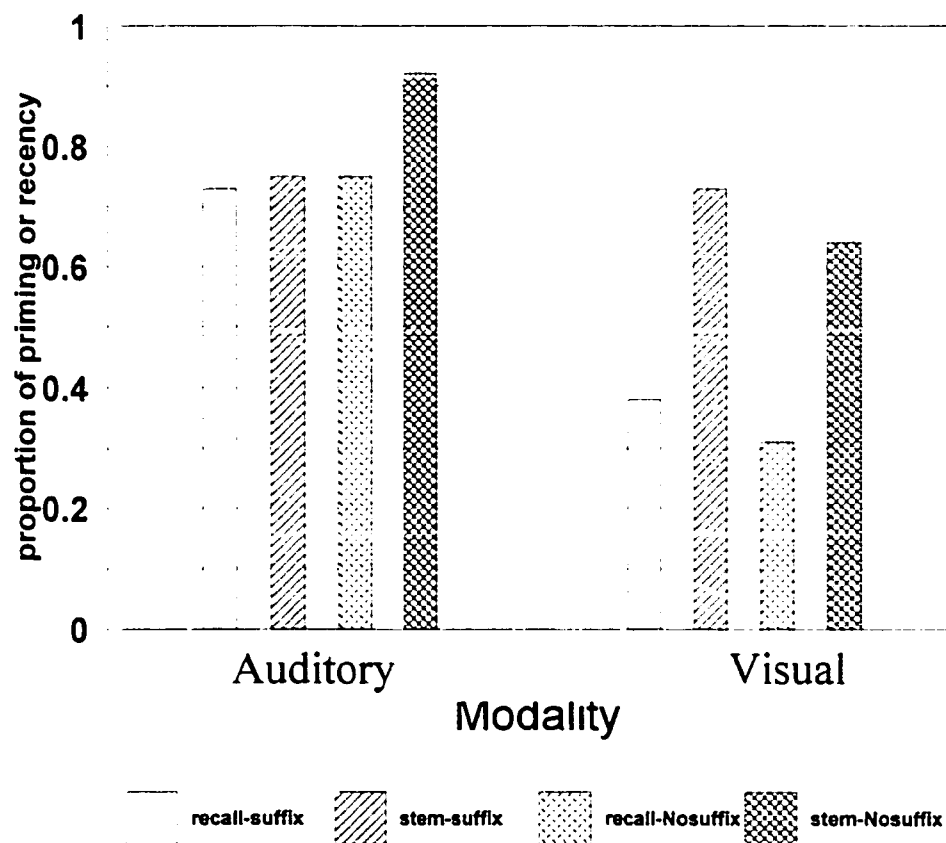
**Figure 5a :** Experiments 1 and 2: Interaction of Task X Modality X Suffix

Table 5g

**Results of Fisher Exact Tests Performed Between the Auditory and Visual Conditions for the Interaction of Task X Modality X Suffix of Experiments 1 and 2**

## Recency Suffix

	Outcome Yes	Outcome No
Auditory	35	13
Visual	18	30

Fisher Exact  
p= .0009

## Recency Non-suffix

	Outcome Yes	Outcome No
Auditory	27	9
Visual	11	25

Fisher Exact  
p= .0003

## Priming Suffix

	Outcome Yes	Outcome No
Auditory	36	12
Visual	35	13

Fisher Exact  
p= 1

## Priming Non-suffix

	Outcome Yes	Outcome No
Auditory	33	3
Visual	23	13

Fisher Exact  
p= .0009

Table 5h

**Results of Fisher Exact Tests Performed Between the Priming and Recency Conditions for the Interaction of Task X Modality X Suffix in Experiments 1 and 2**

## Suffix Auditory Condition

	Outcome Yes	Outcome No	
Priming	36	12	Fisher Exact $p= 1$
Recency	35	13	

## Suffix Visual Condition

	Outcome Yes	Outcome No	
Priming	35	13	Fisher Exact $p= .0009$
Recency	18	30	

## Non-suffix Auditory Condition

	Outcome Yes	Outcome No	
Priming	33	3	Fisher Exact $p= .111$
Recency	27	9	

## Non-suffix Visual Condition

	Outcome Yes	Outcome No	
Priming	23	13	Fisher Exact $p= .0089$
Recency	11	25	

In summary, the results from the analysis of the data for Experiment 1 and Experiment 2 combined, confirmed that the presentation of a digit at the end of the target list in Experiment 1 did not produce a suffix effect. An explanation for this lack of effectiveness of the suffix may be explained by the literature. Watkins and Peynircioglu (1983), were able to obtain three simultaneous recency effects, by presenting participants with words of three different categories within the same list. Thus, the last word presented did not act as a suffix for the words from different categories presented before it. Furthermore, Gardiner and Gregg (1979), found no suffix effect when the suffix was provided by instructing the participants to count backwards, before and after each to be remembered item, including the last one. This evidence supports the results found in this experiment, that when information from different categories is presented within the same list, the item presented last does not reduce recency in the other category.

The results of the combined analysis for Experiments 1 and 2 also confirmed dissociations between priming and recency. Recency appears to be affected by presentation modality more than priming. On the other hand, priming appears to be affected by the frequency of the stimuli more than recency.

### EXPERIMENT 3

In Experiment 3, after each one of the first six lists, the participants instead of being asked to recall the numbers presented, were asked to recall the words. This condition was designed to shed some light on the effects of focusing the participants' attention on the target words. In particular, we were interested in how this new procedure would affect recall and priming, in an attempt to provide evidence for similarities and differences between priming and recency. The main purpose of performing Experiment 3 was to provide a contrast for Experiment 2, so that we can test the effects of distracting the participants attention away from the target list, by asking them to recall the digits during the first six lists, and then comparing this to a condition where the participants' attention was directed towards the target list. Only one of the conditions used in Experiment 2 was used for Experiment 3. The low frequency visual condition was selected because it was the one where priming and recency were most different. In the low frequency condition of Experiment 2, priming was seen in 89 % of the participants, while only 38 % of the participants showed recency. If the low level of recency, as compared to priming, was due to the distractor activity of having to recall the digits during the first six lists, then the difference between priming and recency should diminish by focusing the participants' attention on the words. On the other hand, if the difference between priming and recency remains the same, then there would be further evidence of a dissociation between priming and recency.

#### Method

### Participants

Participants for Experiment 3, (11 males and 25 females) were recruited at Hunter College of the City University of New York. All 36 participants were between 18 and 35 years of age, and had English as their first language.

### Experimental Design

In Experiment 3 only the visual, low frequency condition was used, for reasons described above.

### Procedure

All the stimuli were presented on a Relisys 14" monochrome display monitor. A customized software program generated the list of words and numbers to be presented in the appropriate order.

The stimuli, order of presentation, timing, and type of presentation were the same as in Experiment 2, with the exception that at the end of each one of the distractor lists, the participants were instructed to recall as many words as they could from the previously presented list of words and numbers.

## RESULTS AND DISCUSSION

The results regarding the number of target words recalled, as well as the number of stems completed using the words presented in the target list, were tallied for each serial position, for each presentation modality and for each word frequency condition. Figure 6 is a graphic representation of these results. In all conditions, the priming measure was adjusted by subtracting the baseline level of priming from the number of stems completed,

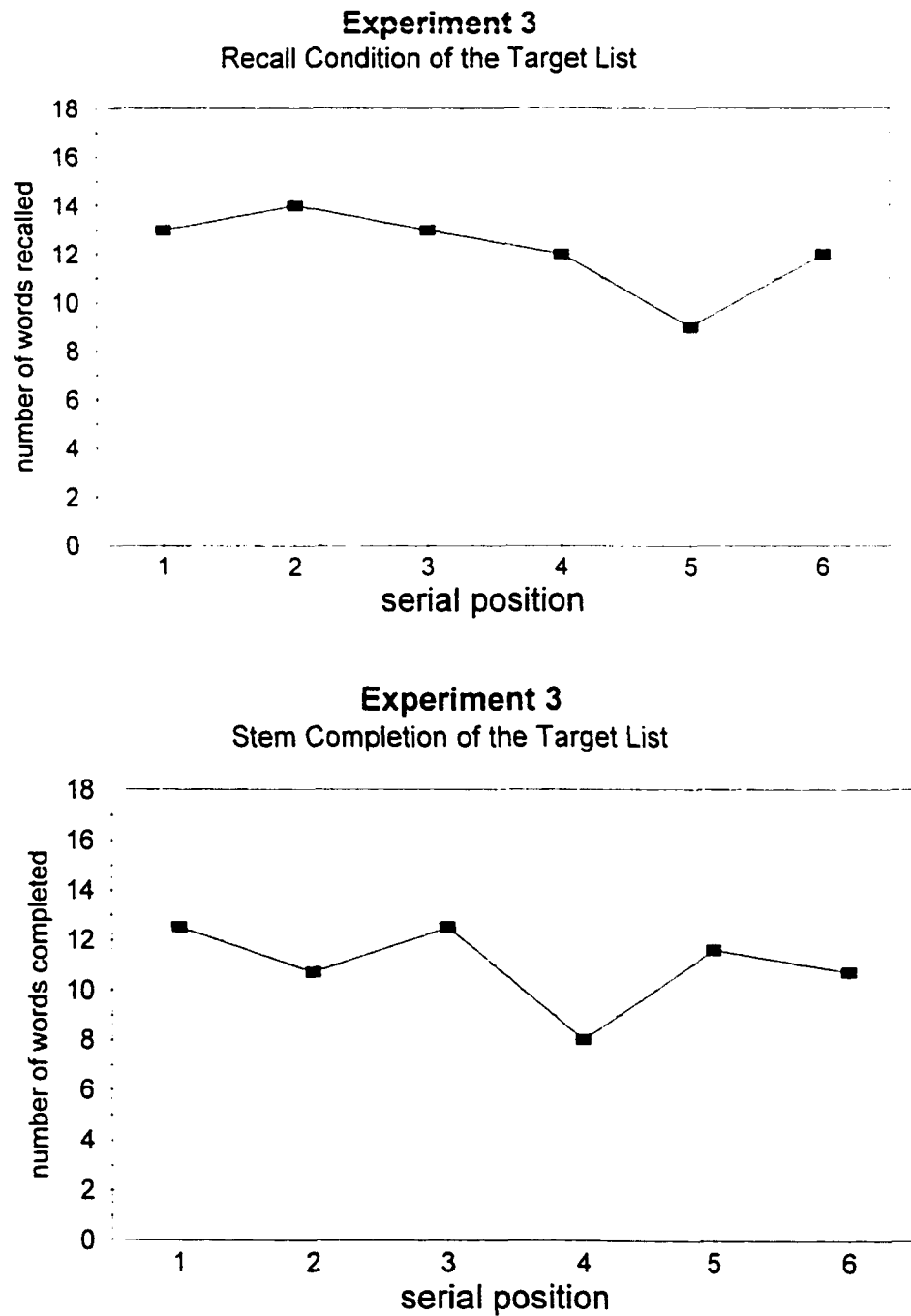
in order to obtain a pure measure of priming. The baseline level for the target words was obtained using 288 participants, 144 from Experiment 1, and 144 from Experiment 2. The baseline level for low frequency words was 11%.

The graph on the upper portion of Figure 6 represents the total number of words recalled from the target list in the recall condition of Experiment 3. The graph on the lower portion of Figure 6 represents the total number of words from the target list used in the stem completion condition.

As can be seen in the figure, there was a primacy effect for the proportion of words correctly recalled for the target list. Participants were better able to recall words that were presented at the beginning of the list, and performance decreased with serial position. This pattern continued until position five, but then performance increased for position six, suggesting that recall may have been affected by a recency effect.

The serial position curve produced by the proportion of appropriate words used in the stem completion task is not as clear. The curve appears to be flat, with a noticeable decrease in performance in position four. This decrease in performance in the middle of the curve is not typical of most serial position curves, and unexplainable.

**Figure 6: Serial Position Results from the Low Frequency, Visual Conditions in Experiment 3.**



In addition to the data described above, the results from the recall of the distractor lists were also collected. Figure 7 is a graphic representation of these results. As can be seen in Figure 7, as expected, the recall of words in the first six lists was almost identical in the two conditions. In fact, the stimulus presentation and instructions to the participants in the first 6 lists of the recall and stem completion condition of Experiment 3 were identical, and therefore the results were also expected to be similar.

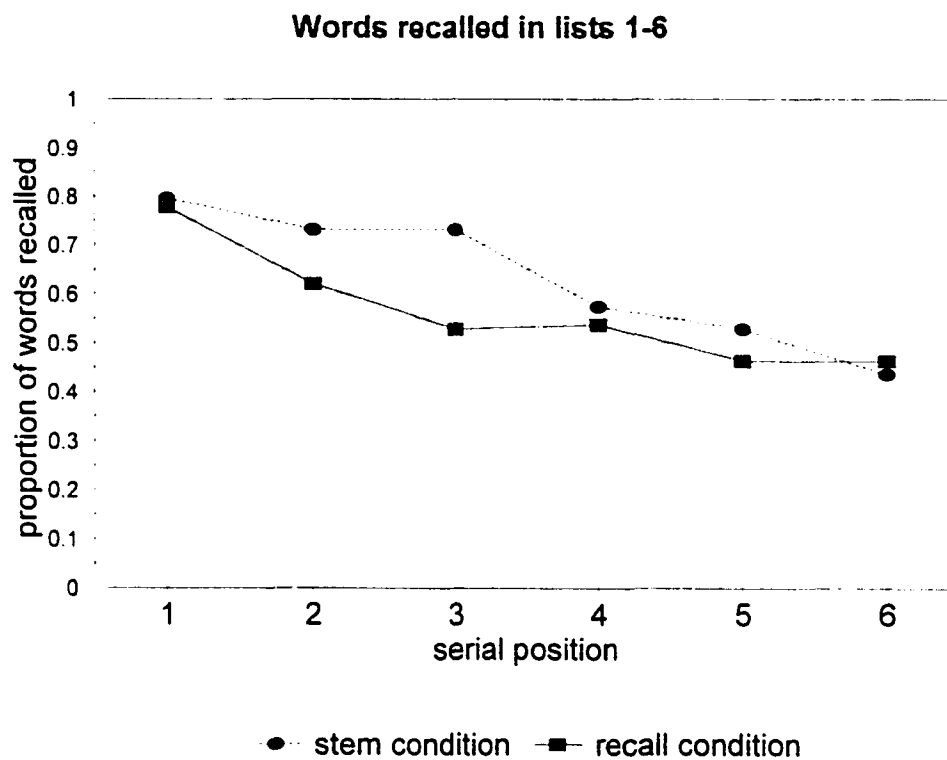
An analysis of variance (ANOVA), was conducted on the data obtained in the two conditions of Experiment 3, that included the results from the recall of the distractor lists, as well as the recall or stem completion of the target list. This resulted in a 2 (condition) X 7 (list) X 6 (position) ANOVA. The analysis revealed a significant main effect of list,  $F(6, 204) = 9.98$ ,  $MSE = 37.378$ ,  $p < .0001$ . This effect is caused by a difference between the different lists. Figure 8a is a representation of these results. It appears that recall is better for the lists presented last. There is an increase in recall for list 6 as well as for list 7. The increase in list 7 is not as great as list 6, possibly because of the change in frequency between the words in the distractor lists and the ones in the target list.

The analysis also indicated a main effect of position,  $F(5, 170) = 13.57$ ,  $MSE = 41.133$ ,  $p < .0001$ . This effect is caused by a difference between the serial positions. Figure 8b is a graphic representation of these results. As can be seen in Figure 8b there is no recency, when the results of the different lists are collapsed, in the different positions. Furthermore, there appears to be a primacy effect, in fact, the best performance was obtained in position 1, and performance then gradually decreased until position 6.

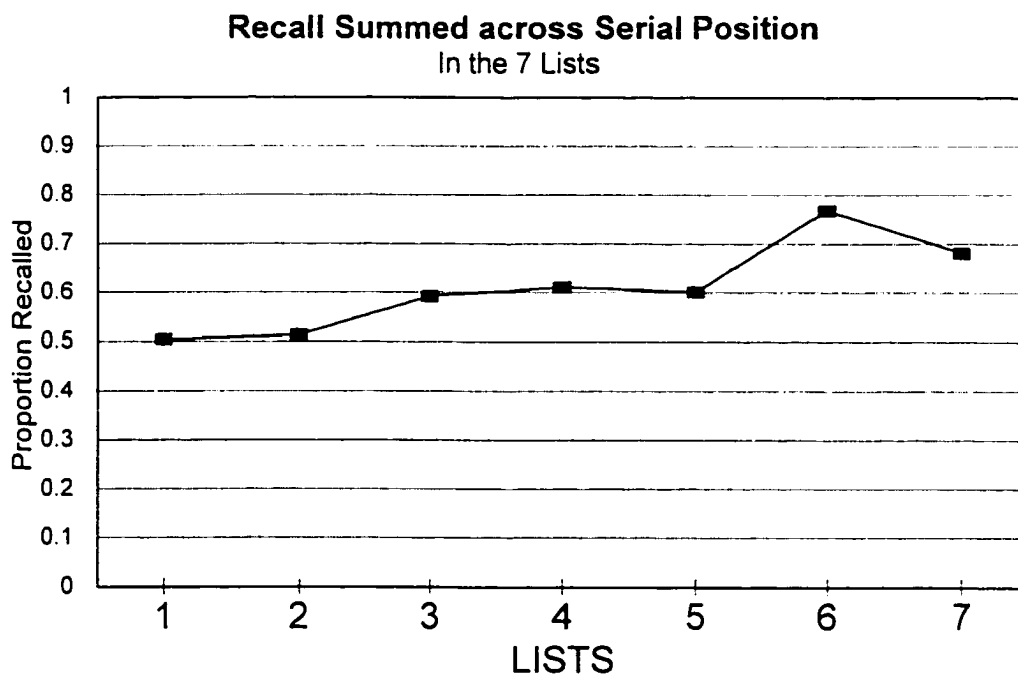
The most interesting results from the analysis described above, that relates to the similarities and differences between priming and recency, can be found in the non significance of the main effect of task. Even though these results do not directly compare priming and recency, a comparison is made between priming and recall. Because recall is the test most often used to measure recency, it becomes possible to argue that a similarity between results obtained using priming and recall could reflect a similarity in priming and recency.

The results obtained in Experiment 3 are important in their own right. But the main reason for conducting Experiment 3, as previously discussed, was to be able to compare its results to the results from Experiment 2.

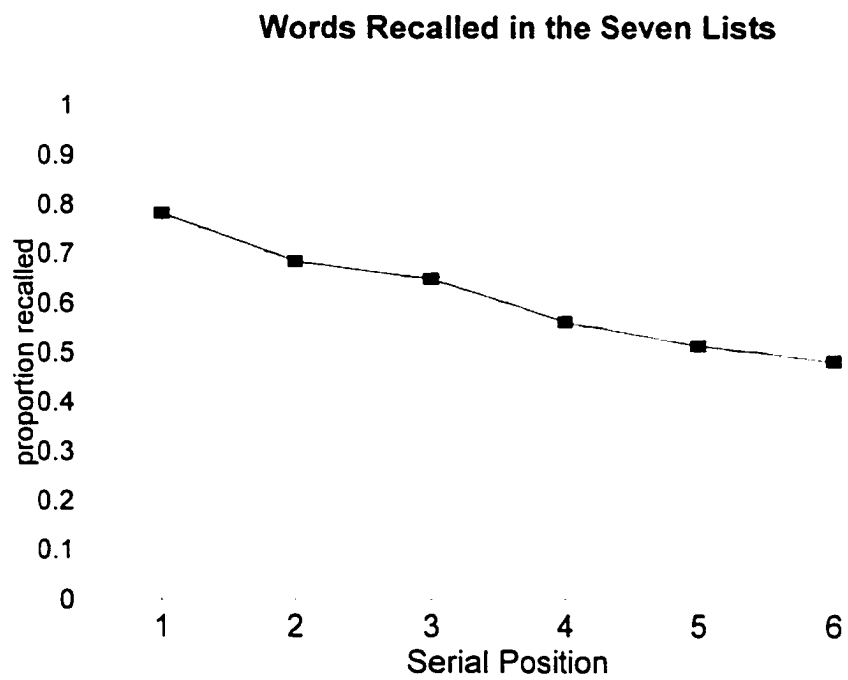
**Figure 7:** Experiment 3: Serial Position Results from the Distractor Lists



**Figure 8a:** Experiment 3: Main Effect of List



**Figure 8b:** Experiment 3: Main Effect of Serial Position



## ANALYSIS OF EXPERIMENTS 2 AND 3

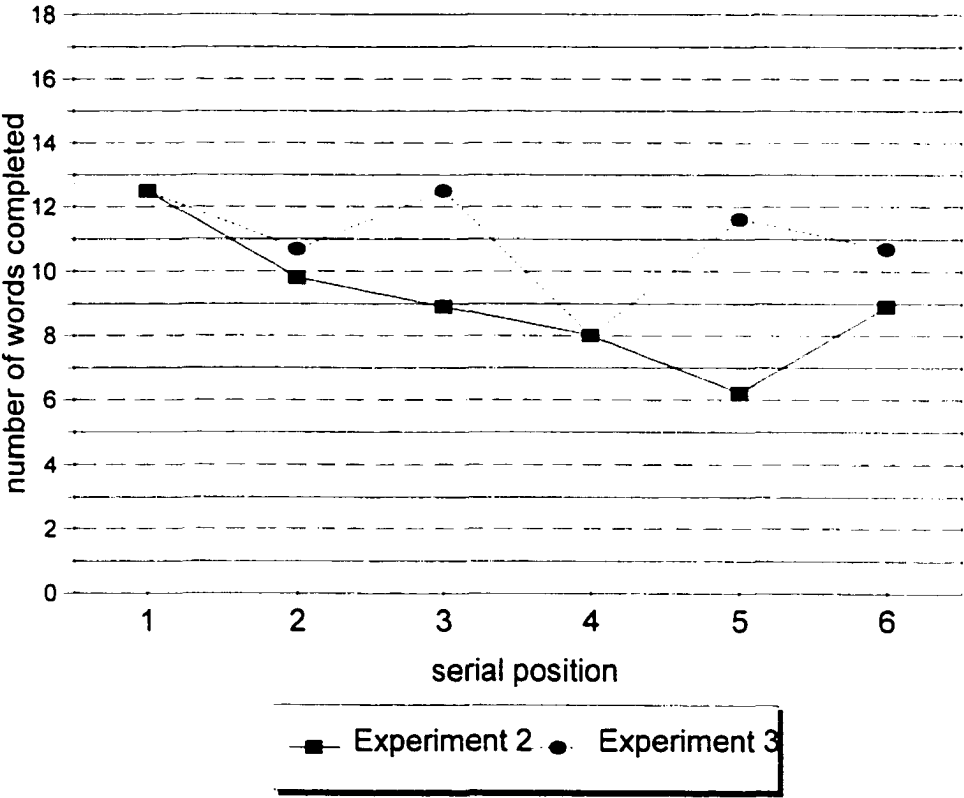
Of additional interest was the question of whether the instruction given to the participants during the first 6 lists would change the results obtained for the target list, for both the recall, as well as the stem completion condition. This analysis would require us to compare the results obtained in Experiment 2 to the one obtained in Experiment 3.

The results from the two conditions of Experiment 3 were compared with the results from the same conditions in Experiment 2. This would allow us to determine if the task performed by the participants in the first six lists would influence the performance on list seven, the target list.

## RESULTS AND DISCUSSION

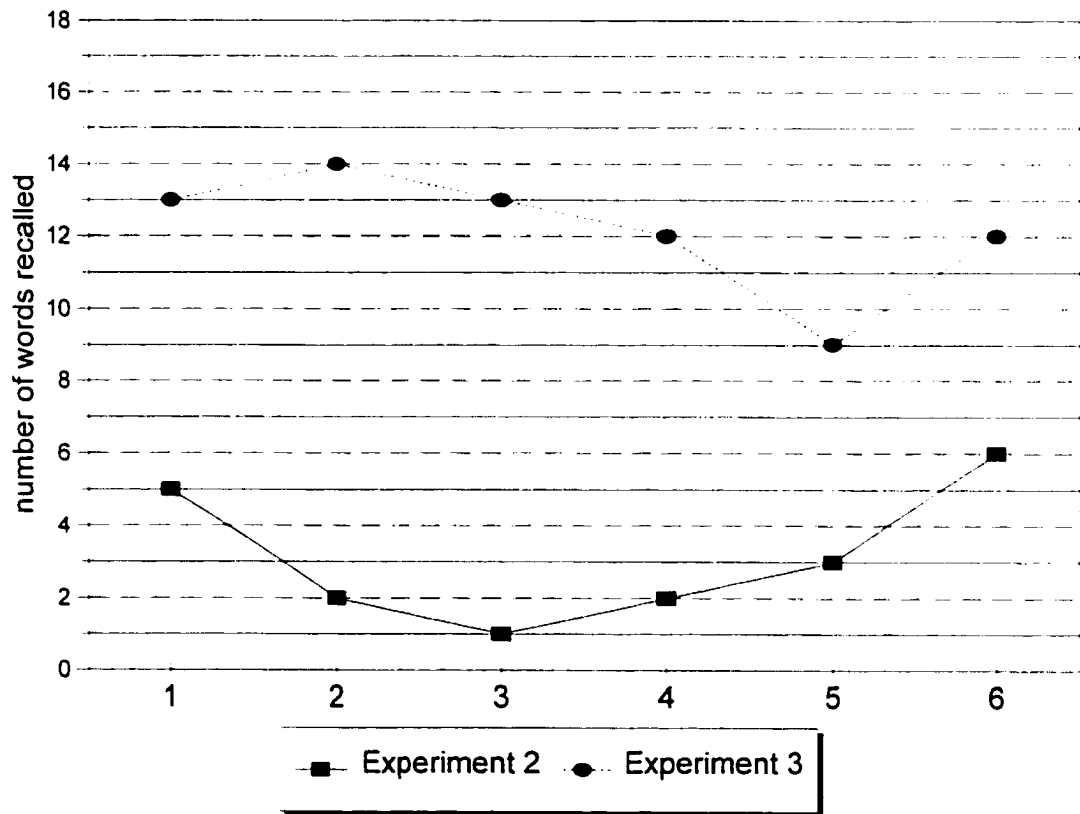
First of all, the results from the target list of the stem completion conditions were compared. As Figure 9a shows, even though the stems appropriately completed were greater in number in Experiment 3 than in Experiment 2, the difference between the two is not great.

**Figure 9a: Stem Completion of Target Words in Experiments 2 and 3**



On the other hand the difference between the results of the target list from Experiments 2 and 3 is much greater in the recall condition. Unlike the stem completion condition, where the results in several serial positions in the two experiments are very similar, if not identical, the results from the recall condition of the two experiments differ greatly. As can be seen from Figure 9b, recall of the target list in Experiment 3 was much better than the recall of the same list in Experiment 2. These results were expected since, during the first 6 lists of Experiment 2, the participants were asked to recall the digits from the lists, while in list 7 they were asked to recall the words. On the other hand in Experiment 3 during the first 6 lists the participants were asked to recall the words from the lists presented, and they were asked to do the same in list 7. Therefore in Experiment 3, during recall of the target list the participants could benefit from practice effects, as well as from the effects from paying attention to the relevant stimuli.

Figures 9a and 9b therefore, suggest that stem completion was similar, while recall was different, when comparing Experiments 2 and 3.

**Figure 9b: Recall of Target Words in Experiments 2 and 3**

When the overall number of words recalled or stem completed are compared in the two Experiments, regardless of serial position, an interesting result can be seen. As Figure 9c shows, while in Experiment 2 the number of stems completed was greater than the number of words recalled, in Experiment 3 the opposite occurred. In Experiment 3 the number of words recalled was greater than the number of stems primed. A related result is that recall of words in Experiment 2 is much lower than in all the other conditions. A One-Way ANOVA was performed on the data depicted in figure 9c. The results of the analysis was significant,  $F(3,68) = 24.76$ ,  $MSE = 37.12$ ,  $p < .01$ . This significant analysis suggested that there was a significant difference between the four conditions.

The results depicted in Figure 9c can be explained by the difference in presentation method, and how the level of recall in Experiment 3 was increased by previous exposure to a similar test, and increased attention to the relevant stimuli, while recall in experiment 3 was negatively affected by the novelty of the test. An interesting aspect of these results is that they show how stem completion is an implicit memory process, and performance is not affected by the participants' awareness of the stimuli presented. In fact, stem completion does not differ greatly between Experiments 2 and 3. On the other hand recall is an explicit memory process, and the awareness of the participants in regard to the stimuli is extremely important. In fact, recall in Experiment 2 is much poorer than recall of the same stimuli in Experiment 3. A Tukey hsd test was used to determine which of the groups were significantly different from each other. The difference between the means of the groups can be seen in Table 6.

**Figure 9c: Number of Target Words Recalled and Used in Stem Completion**

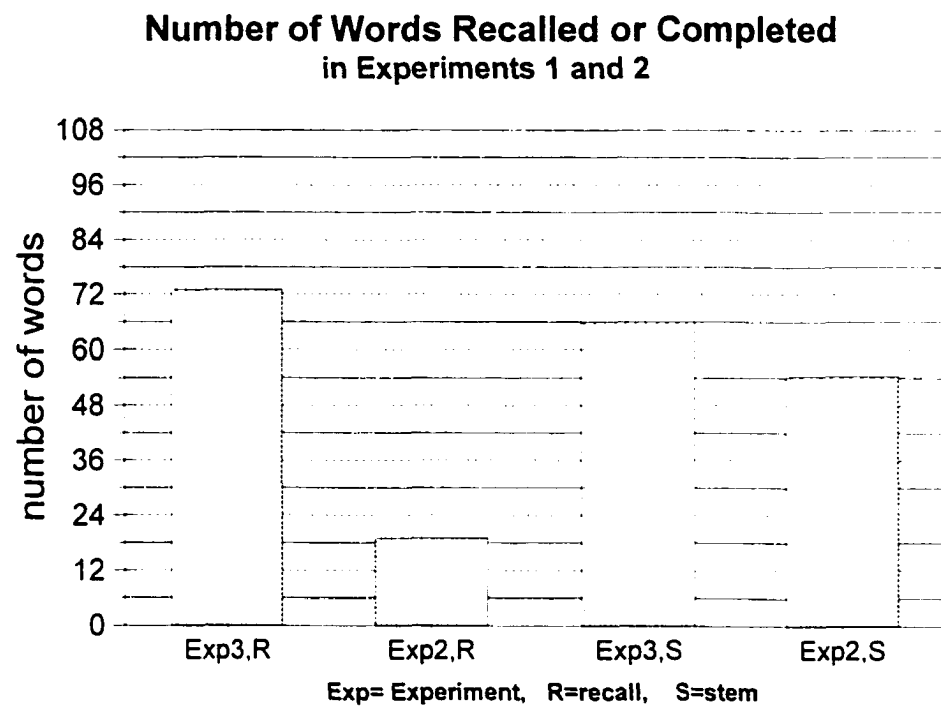


Table 6

**Results of a Tukey hsd Test on the Comparison Between Experiments 2 and 3**

	Stem Exp. 2	Recall Exp. 3	Stem Exp. 3
Recall Exp. 2	2.333*	3.0**	3.056**
Stem Exp. 2		.675	.723
Recall Exp. 3			.056

Note. \*\* hsd at  $\alpha .01 = 2.816$

\* hsd at  $\alpha .05 = 2.290$

The Tukey hsd test revealed a significant difference between the recall condition of Experiment 2 and all the other conditions. Furthermore, there was a significant difference between the recall conditions of Experiments 2 and 3, while there was no significant difference between the stem completion conditions of the two Experiments.

Thus, the results described above suggest that our manipulation of the procedure in Experiment 3 did not make a difference in the stem completion task. However, in the recall task, participants in Experiment 3 were able to perform significantly better than the participants in Experiment 2. These results support an extensive amount of literature indicating that in implicit memory tasks participants do not need to be aware of the stimuli presented, in order to be affected by them (see Roediger and McDermott, 1993).

As previously discussed, a difference between the overall values of recall and stem completion is not enough to establish a difference between priming and recency. In order to do that the values of priming and recency have to be derived from the results.

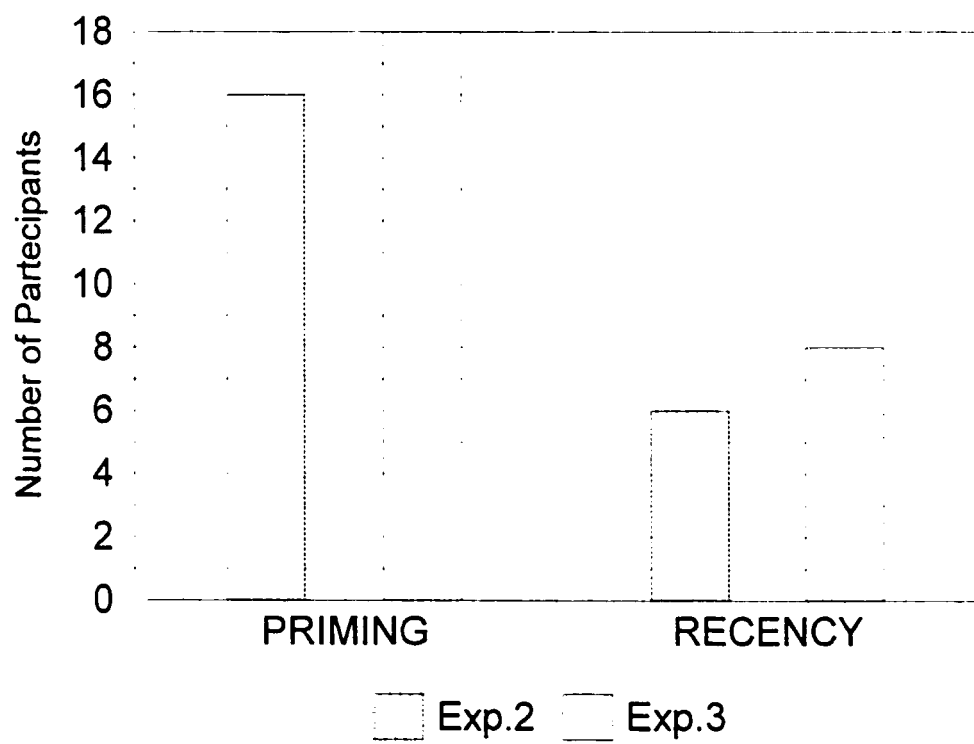
#### METHOD FOR SCORING PRIMING AND RECENCY

The method adopted for scoring priming and recency was the same as the one used in Experiment 1. The priming and recency results from the four non-suffix conditions are depicted in Figure 9d. In this figure it appears that the pattern of variation between priming and recency remains the same in the two Experiments. The only difference is that performance in Experiment 3 is better, for both priming and recency, than in Experiment 2. Thus these results would suggest that directing the participants' attention, prior to the presentation of the target list, to the relevant stimuli, does not affect priming and recency

in different ways. On the contrary, both effects appear to be affected in the same way.

Increasing attentiveness to the target stimuli increases performance in both priming and recency effects.

**Figure 9d : Number of Participants Showing Priming or Recency in Experiments 2 and 3**



As in Experiments 1, 2, and 3, a log-linear analysis was performed on the results of priming and recency. This analysis was a 2 Task (priming and recency) X 2 Experimental Condition (Experiment 2 and Experiment 3) design. The logit-model analysis confirmed what appeared to be the case, as previously discussed. A main effect of task was significant,  $\chi^2(1) = 28.08, p < .0001$ . This main effect was due to greater priming than recency in both Experiments. Table 6a depicts four Fisher Exact tests done for Task and Experimental Condition. There was a significant difference for priming and recency in Experiment 2,  $p = .0015$ , and in Experiment 3,  $p = .0003$ . On the other hand, there was no significant difference for priming in Experiments 2 and 3,  $p = .485$ , nor for recency in Experiments 2 and 3,  $p = .733$ .

In the log-linear analysis, neither the main effect of Experimental Condition, nor the interaction of Task X Experimental Condition, were significant. These non significant results means that there was no significant difference between the two experiments, in terms of the number of participants showing priming and recency combined, as well as separately.

Table 6a

**Results of Fisher Exact Tests Performed Between the Priming and Recency Conditions of Experiments 2 and 3**

## Experiment 2

	Outcome Yes	Outcome No
Priming	16	2
Recency	6	12

Fisher Exact  
p= .0015

## Experiment 3

	Outcome Yes	Outcome No
Priming	18	0
Recency	8	10

Fisher Exact  
p= .0003

## Priming

	Outcome Yes	Outcome No
Experiment 2	16	2
Experiment 3	18	0

Fisher Exact  
p= .485

## Recency

	Outcome Yes	Outcome No
Experiment 2	6	12
Experiment 3	8	10

Fisher Exact  
p=.733

In all the Experiments described in this study, the presence of priming and recency was indicated by a level of that effect that was greater than criterion levels. For priming that level had been obtained by using as a baseline, the stem completion performance of participants who were not presented with the target words, while for recency that criterion level was the average of the recall of the words presented in the middle of the list. Both methods are consistent with the definitions of priming and recency. Therefore, the significant difference shown by the main effect of Task may be interpreted as an indication that the priming and recency effects may be part of different processes.

The main effect of Task, together with the non significant difference between Experiments 2 and 3, provide further evidence of a dissociation between priming and recency by validating the method used in Experiments 1 and 2. Experiments 1 and 2, revealed a significant main effect of Task, which was due to the greater amount of priming as compared to recency. If the low level of recency, as compared to priming, was due to the distractor activity of having to recall the digits during the first six lists, then the difference between priming and recency should have been diminished by focusing the participants attention on the words, as was done in Experiment 3. However, as reported above, there was no significant difference between Experiments 2 and 3, and in Experiment 3 priming was still significantly greater than recency. Therefore, these results provide further evidence of a dissociation between priming and recency.

## ADDITIONAL RESULTS

In addition to the primary results described above, in the current experiment, a number of other results were obtained. At the end of the experiment all the participants were asked to recall as many words as they could, that were presented during the entire experiment. Thus, for all the participants there was a delayed recall score. Participants in the recall condition, after the recall, were asked to complete the same stem completion list that was completed by participants in the stem completion condition. Furthermore, all the participants were asked to complete a stem completion list, that could be completed using some of the words presented in the distractor lists.

These results allowed for several comparisons that follows.

### IMMEDIATE AND DELAYED RECALL OF THE TARGET LIST

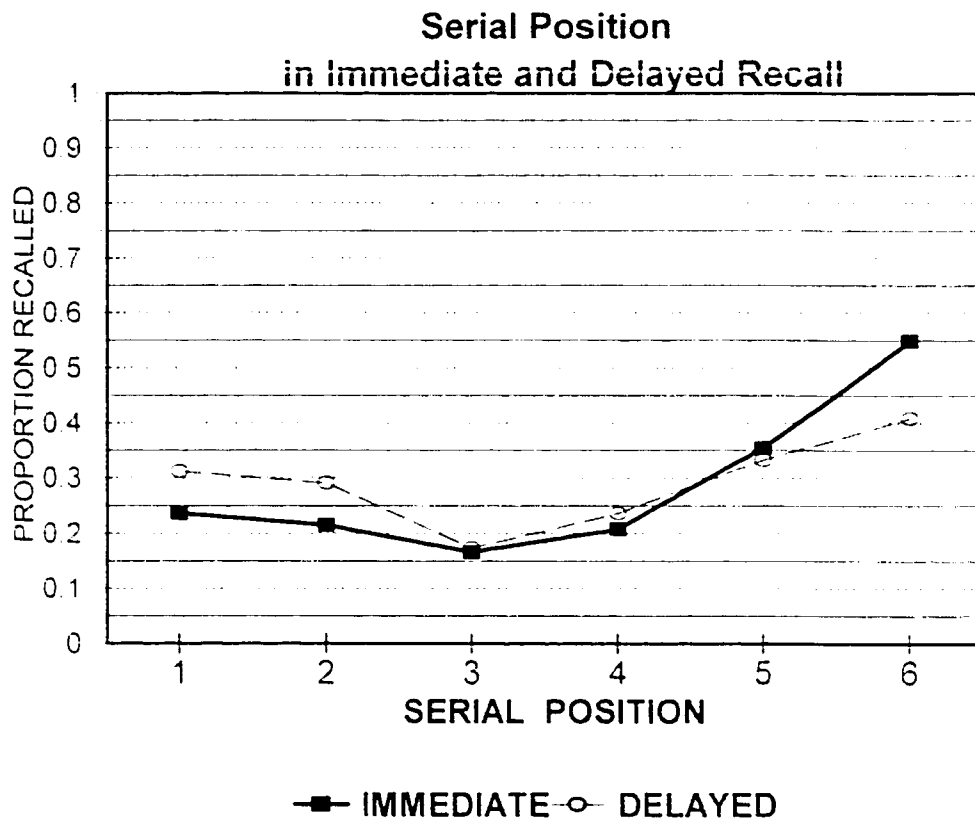
Since data were collected on the number of target words that participants recalled at the end of the experiment, immediate and delayed recall could be compared, to determine if there were any differences between the two kinds of recall in the different conditions. In order to answer this question, a 2 Task (immediate and delayed recall) X 2 Suffix (suffix and non-suffix) X 2 Modality (auditory and visual) X 2 Frequency (high frequency and low frequency) X 6 Serial Position. ANOVA was performed on the data obtained from the recall conditions.

In this analysis, a significant interaction, of Task X Serial Position was found,  $F(5,680) = 9.19$ ,  $MSE = 34.17$ ,  $p < .0001$ . As can be seen in Figure 10a, both serial position curves, for the immediate and delayed recall, follow the expected pattern, showing some

primacy and recency.

The two curves are very similar in serial positions 3, 4, and 5. The main differences between the two curves occur in positions 1 and 2, where delayed recall shows greater primacy than immediate recall. The other difference occurs at position 6 where immediate recall shows greater recency than delayed recall. Fisher Exact tests indicated that there was no significant difference for immediate and delayed recall in position 1,  $p = .186$ , or position 2,  $p = .175$ , while there was a significant difference for immediate and delayed recall in position 6,  $p = .024$ . Furthermore, a comparison of positions 1 and 3 in immediate recall was not significant,  $p = .185$ , suggesting that there was no primacy effect, while in delayed recall a significant difference was found,  $p = .0087$ , indicating that the primacy effect was present.

The lack of priming in the immediate recall condition is not surprising, since several prior papers have shown that in incidental learning tasks, where recall is a surprise, the primacy effect is eliminated (see Baddeley and Hitch, 1977; Glenberg et al., 1980). A more important aspect of these results is the finding that primacy is restored in delayed recall. These results fit the original view from the Modal Model (Atkinson and Shiffrin, 1968), of STM and LTM, where recency is thought to be a result of STM, and primacy is a result of LTM. At the same time, these results discredit the model by providing evidence of long term recency, that the Modal Model cannot explain.

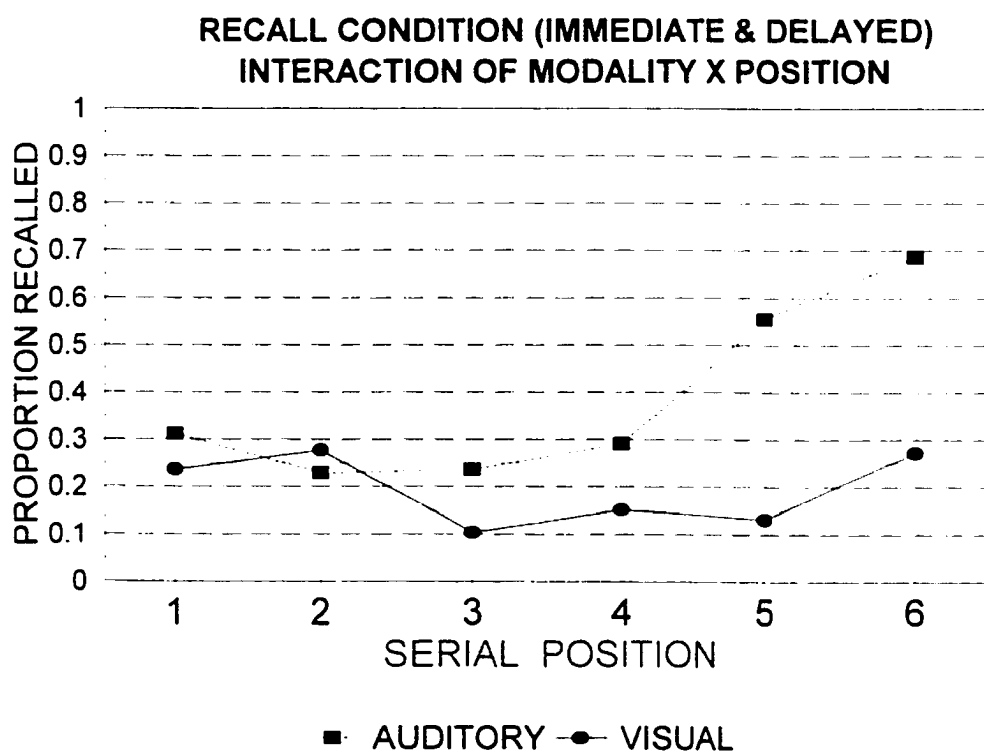
**Figure 10a: Interaction of Task X Position in Immediate and Delayed Recall**

Furthermore the analysis of the data show an interaction of Modality X Position,  $F(5,680)= 8.71$ ,  $MSE= 204.25$ ,  $p< .0001$ .. As can be seen in figure 10b, as expected, the auditory modality produced a greater recency effect than the one produced by the visual modality. More specifically the difference between the serial position curves produced by the two modalities is greatest in serial positions five, and six. For position 5, the mean for the two modalities is greatest in serial positions five, and six. For position 5, the mean for the visual condition is .132, while for the auditory condition is .555. For position 6, the mean for the visual condition was .271, and for the auditory condition was .687.

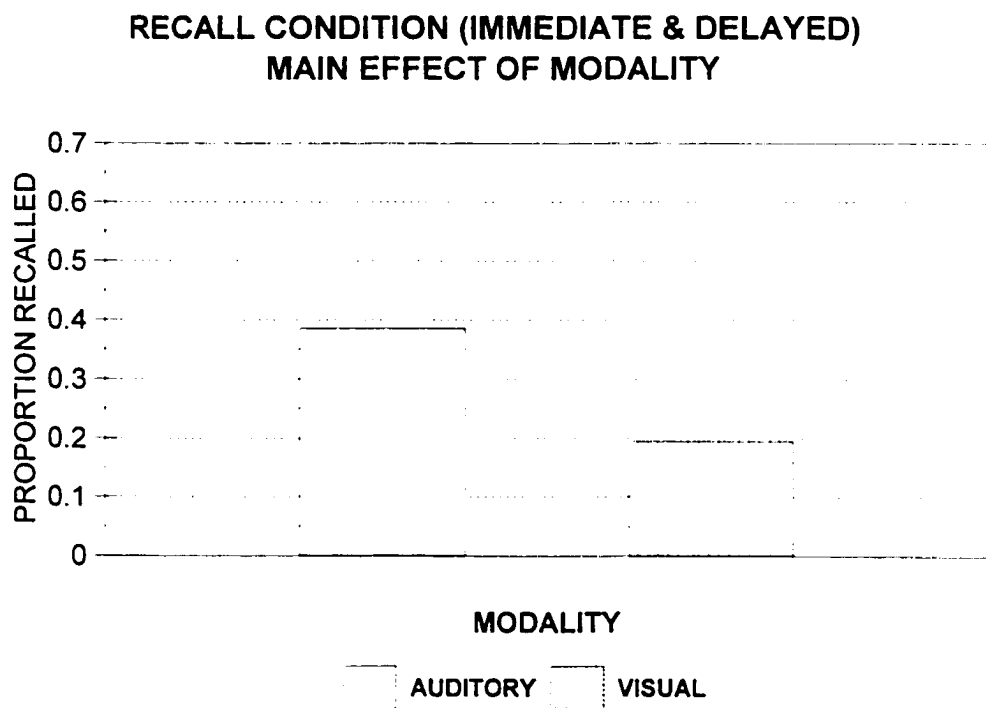
A main effect of modality was also found, indicating a significant difference between the auditory and the visual presentations,  $F(1, 136) = 41.99$ ,  $MSE= 50.04$ ,  $p< .0001$ . As can be seen in Figure 10c, recall in the auditory modality was greater than in the visual modality. More specifically, the proportion of words accurately recalled in the auditory modality was .385, while the same proportion in the visual modality was .195.

Analysis of the same data also indicated a main effect of serial position,  $F(5, 680)= 11.35$ ,  $MSE= 204.25$ ,  $p< .0001$ . The mean for each serial position, from the first to the last were, .274, .253, .170, .222, .343, .479. This points to a significant difference between the different serial positions. As illustrated in Figure 10d this result is due to a primacy effect, as well as an even stronger recency effect.

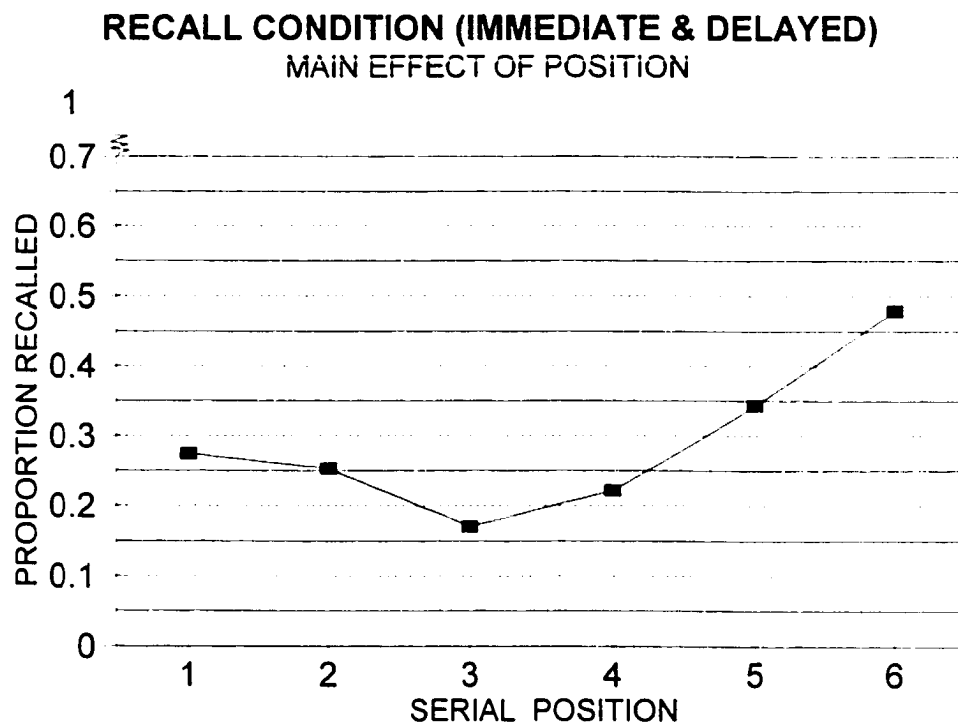
**Figure 10b: Interaction of Modality by Position in the Immediate and Delayed Recall Condition.**



**Figure 10c: Main Effect of Modality in the Immediate and Delayed Recall Condition**



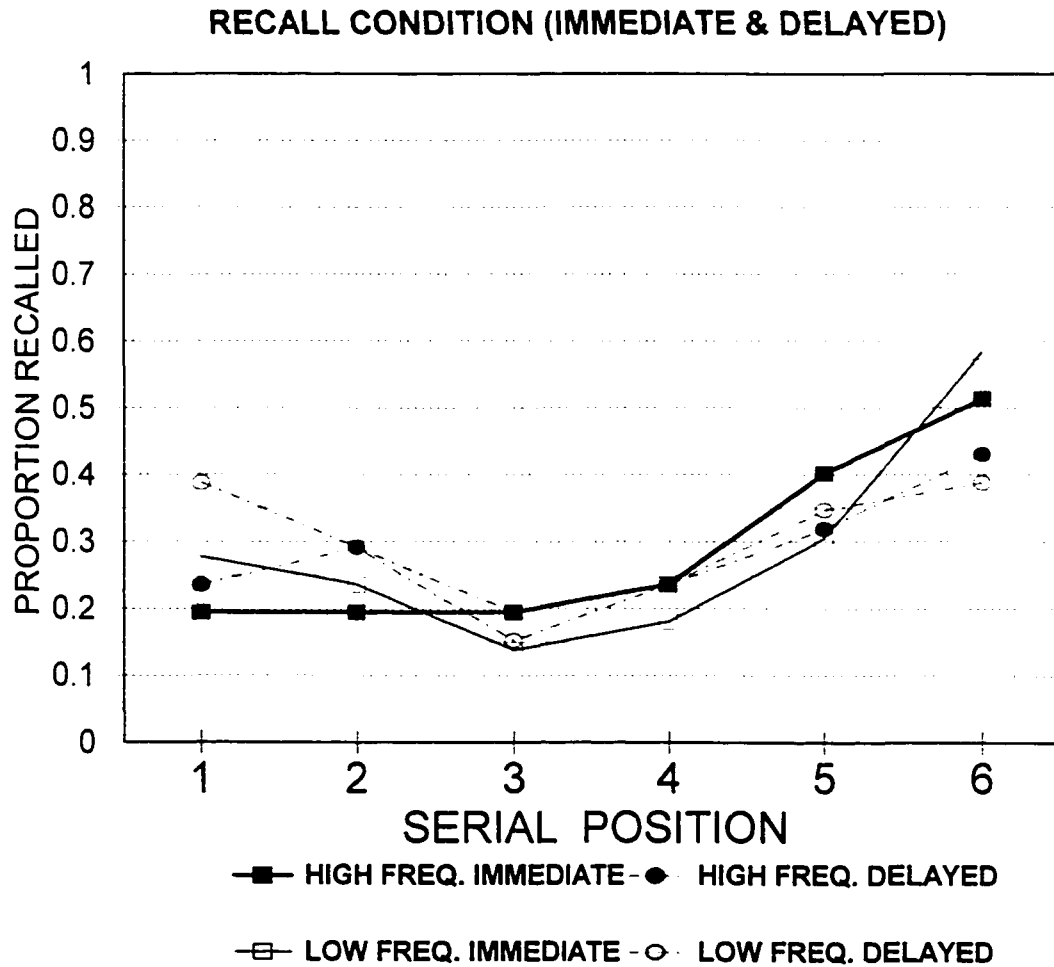
**Figure 10d: Main Effect of Position in the Immediate and Delayed Recall Condition.**



Of final concern regarding the data of immediate and delayed recall, is the significant interaction of Task X Frequency X Position,  $F(5, 680) = 2.56$ ,  $MSE = 34.17$ ,  $p < .026$ . Figure 10e is a graphic representation of these results, and again the serial position curves appear to follow a normal pattern, with different degrees of primacy and recency, with the only exception being the high frequency immediate condition, where the primacy effect appears to be missing. As in the previous results from the interaction of Task X Position, and not surprisingly, immediate recall appears to produce greater recency, but not as much primacy, while delayed recall appear to lead to greater primacy, but not as much recency.

When we look at Frequency, in the last position of the list, the low frequency immediate recall condition is greater than the high frequency immediate recall condition. However, in the same position, the high frequency delayed recall condition is greater than the low frequency delayed recall condition. At the beginning of the list, a different pattern emerges, the low frequency immediate recall condition is greater than the high frequency immediate recall condition, while the high frequency delayed recall is less than the low frequency delayed recall. Thus primacy effects appear to be influenced a great deal by frequency, with low frequency leading to greater primacy than high frequency. On the other hand, recency appears to be influenced greatly by Task, with immediate recall leading to greater recency than delayed recall. This latter point is consistent with the results obtained for the interaction of Task X Position, and follows previous literature indicating that recency is more pronounced in immediate recall than in delayed recall.

**Figure 10e: Interaction of Task X Frequency X Position in the Immediate and Delayed Recall Conditions**



## DELAYED RECALL AND DELAYED STEM COMPLETION OF THE TARGET LIST

Of additional interest were the data obtained in the delayed recall as compared to the delayed stem completion of the target words. This analysis was done solely on the recall condition, since this was the only condition where there was a delayed stem completion task for the target list. A 2 Task (delayed recall and delayed stem completion) X 2 Suffix (suffix and non-suffix) X 2 Modality (auditory and visual) X 2 Frequency (high frequency and low frequency) X 6 Serial Position. ANOVA was performed. Table 7 represents the significant results of this analysis.

One very interesting result from Table 7 is the significant interaction effect of Task X Frequency,  $F(1, 136) = 4.22$ ,  $MSE = 22.81$ ,  $p < .042$ . Figure 11a shows the data grouped by Task and Frequency. The proportion of words correctly recalled in the high frequency condition was .29 and in the low frequency condition was .30. On the other hand the proportion of words appropriately used to fill the stems, in the high frequency condition was .42, while in the low frequency condition it was .52.

These results support the previous results, obtained in Experiments 1 and 2, where word frequency had an effect on priming, but not on recall. As previously discussed, a stem completion task may be seen as having some of the same characteristics of a recognition task, and a number of researchers have reported a low frequency advantage in recognition tasks. The results described in this section however, makes an even stronger case, since they were obtained using a within subjects design. Thus, within the same group

of participants, the difference between recall and stem completion was greater when the stimuli were low frequency words than when the stimuli were high frequency words. In addition, in the delayed recall task the number of words recalled in the high and low frequency words did not differ, but in the delayed stem completion task, low frequency stimuli led to greater priming.

Low frequency advantage has been found in a variety of tests. Dennis, (1995), as well as Schulman and Lovelace (1970), reported that, in tests of word recognition, performance is better for low as opposed to high frequency words. However, this low frequency advantage appears to be more frequent in implicit memory tasks. In a lexical decision task experiment, Kinoshita (1995), found that low frequency words produced greater repetition priming than high frequency words. In addition, Nicolas and Soderlund (2000), found greater stem completion priming for low frequency words than for high frequency words. Thus, these results support the view advanced by the results of Experiments 1 and 2, indicating a low frequency advantage in stem completion tasks.

**Table 7****Results of the ANOVA on Delayed Recall and Delayed Priming of the Target List**

<i>Source</i>	<i>F</i>	<i>df.</i>	<i>p</i>	<i>MSE</i>
MODALITY	28.08	1, 136	.0001	52.59
TASK	80.70	1, 136	.0001	22.81
POSITION	3.28	5, 680	.0062	176.87
TASK X FREQUENCY	4.22	1, 136	.0417	22.81
MODALITY X POSITION	4.77	5, 680	.0003	176.87
TASK X SUFFIX X MODALITY	4.22	1, 136	.0417	22.81

**Figure 11a : Interaction of Task by Frequency for Delayed Recall and Delayed Priming**

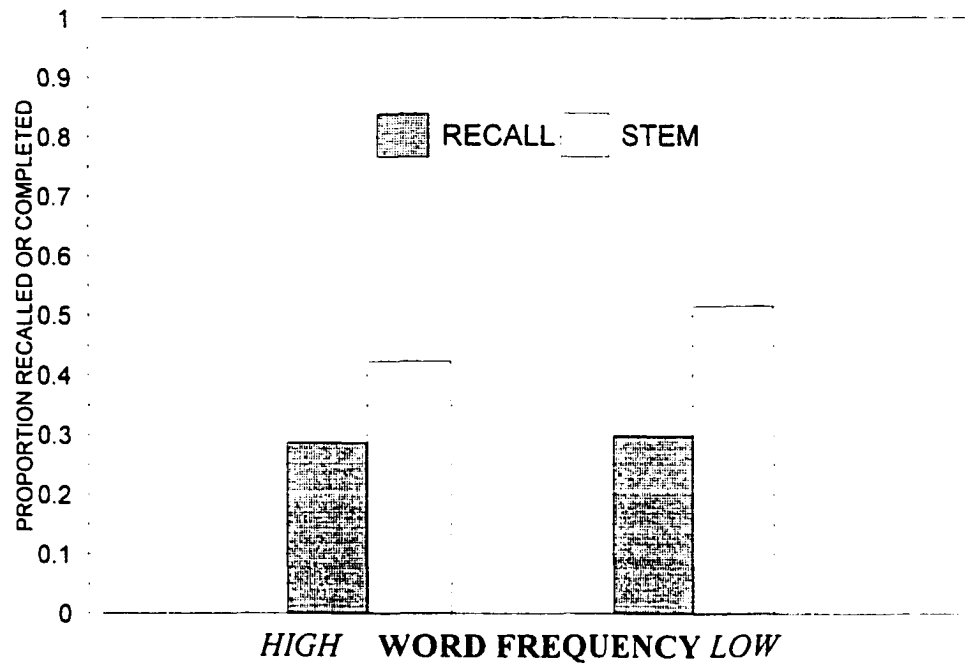


Figure 11b shows the results grouped by Task, Suffix and Modality. This 3 way interaction was significant,  $F(1, 136) = 4.22$ ,  $MSE = 22.81$ ,  $p < .042$ . As the figure indicates there was a large difference between the auditory and visual modality in all conditions except the suffix stem completion condition. More specifically in all conditions, the proportion of words correctly recalled or stems completed in the auditory modality was about .20 better than in the visual condition, except for the suffix stem completion condition, where the proportion correctly filled in, in the auditory condition was .48, and in the visual condition was .42.

Furthermore, there was not much difference between the suffix and non-suffix conditions except in the auditory stem condition, where the proportion of stems appropriately filled in, in the suffix condition was .48, while in the non-suffix condition, it was .59. When looking at the differences in Task, all conditions differ between delayed recall and delayed stem completion, with stem completion always leading to superior performance. All conditions differ by a proportion of approximately .20, with the exception of the auditory suffix condition, where the difference is not as marked. In that condition the proportion recalled is .38, while the proportion of stem completed is .48.

**Figure 11b: Interaction of Task by Suffix by Modality for the Delayed Recall and Delayed Stem Completion Conditions.**

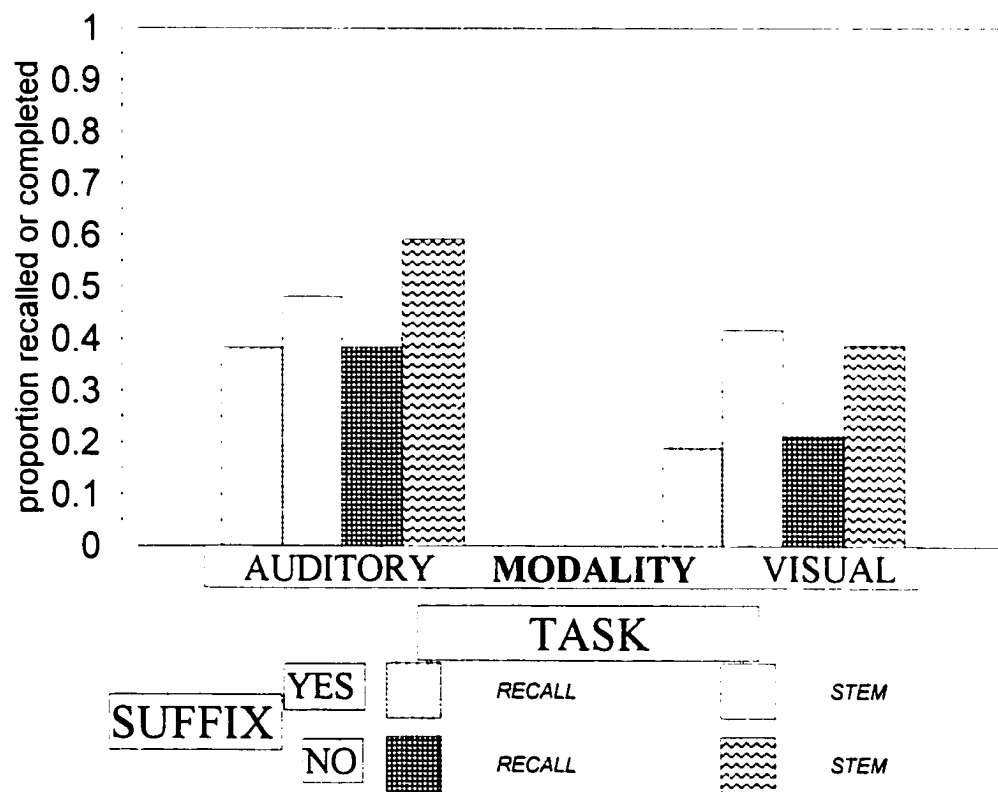
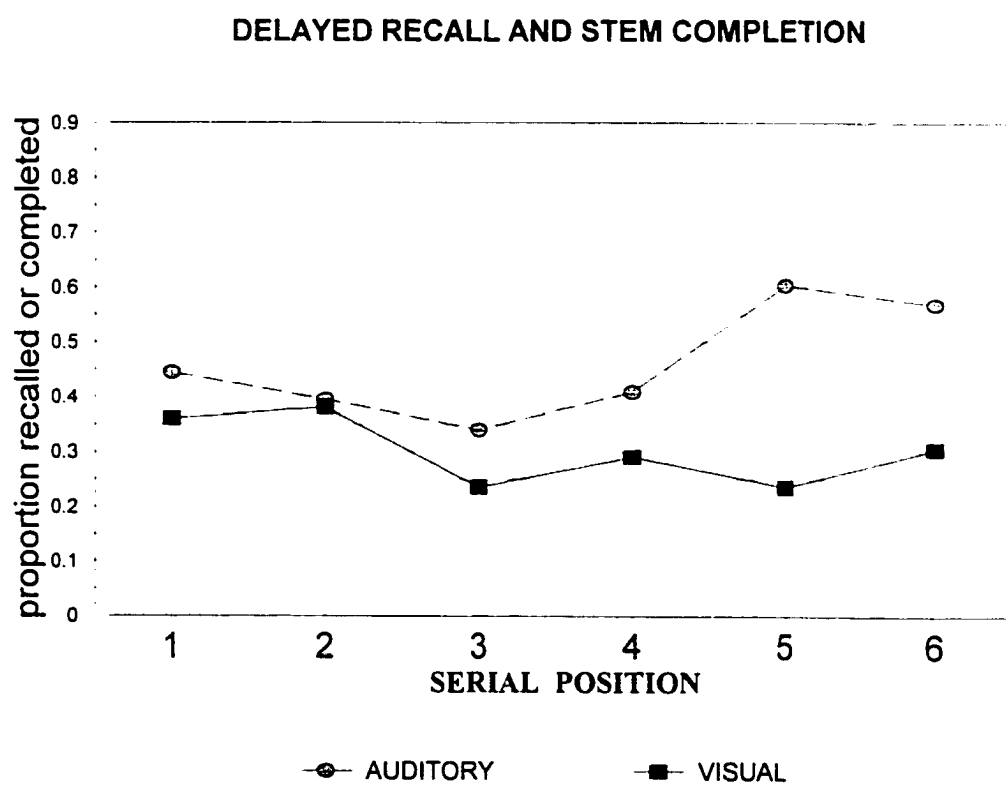


Figure 11c shows the data grouped by Modality and Serial Position. These results led to a significant interaction of Modality X Position,  $F(5, 680) = 4.77$ ,  $MSE = 176.87$ ,  $p < .0003$ . The difference between the serial positions in the auditory condition was greater than the difference between the serial positions in the visual condition. More specifically in the auditory modality there was an increase in performance in position 5 and 6, while the values for all the serial positions in the visual presentation were more uniform.

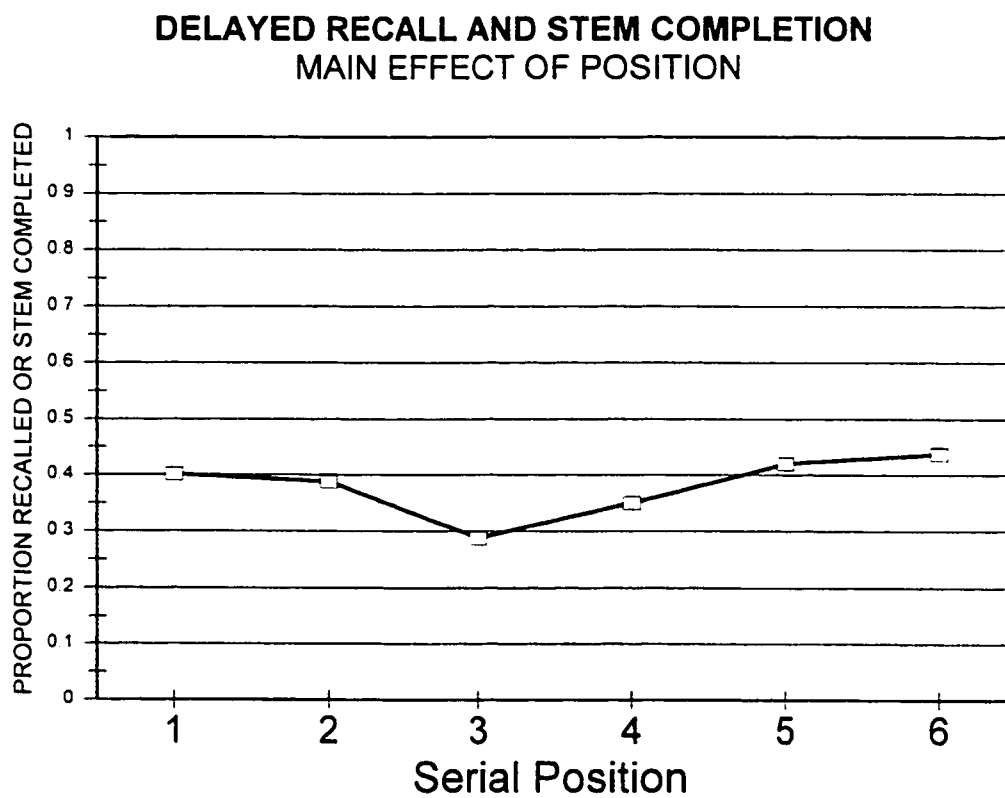
As expected, the auditory condition led to a recency effect that was not present in the visual condition. In fact, as may be seen in Figure 11c, the serial position curves for the two modalities become very different in the last two serial positions, where the auditory presentation leads to much better performance than visual presentation.

**Figure 11c: Interaction of Modality by Position for the Delayed Recall and Delayed Stem Completion Conditions.**



Furthermore, the analysis produced three main effects, a main effect of Modality, Position and Task. As Expected, the main effect of modality,  $F(1, 136) = 28.08$ ,  $MSE = 52.59$ ,  $p < .0001$ , was due to a better performance in the auditory conditions, when compared to the visual. The mean proportion correct for the auditory conditions was .46, while for the visual condition it was .30. The main effect of Position,  $F(5, 680) = 3.28$ ,  $MSE = 176.87$ ,  $p < .0062$ , was due to the primacy and recency effect shown in Figure 11d. The main effect of Tasks,  $F(1, 136) = 80.70$ ,  $MSE = 22.81$ ,  $p < .0001$ , was due to a better stem completion performance than Recall, with the proportion of words correctly completed at .469, while the proportion of words correctly recall at .293.

**Figure 11d: Main Effect of Serial Position in the Delayed Recall and Delayed Stem Completion Conditions.**



## RECALL OF THE FIRST SIX LISTS

In addition to the results mentioned above, the participants were asked, to recall as many words as they could from the whole experiment. This provided a measure of long term recall, of the words presented during the first six lists. The total number of participants for this analysis was 288. In this analysis, the data were collapsed across list and position, because the position of the words was not counterbalanced, and therefore word effects could arise, that may confound serial position effects.

The analysis indicated a main effect of Condition,  $F(1,17) = 56.73$ ,  $MSE = 31.14$ ,  $p < .0001$ . Participants who were in the recall conditions, at the end of the Experiment were able to recall more words from the distractor lists, than participants who were in the stem completion conditions. In the recall conditions, the mean proportion of words recalled from the distractor list was .093, while in the stem completion condition, the proportion of words recalled from the distractor list was .059.

The main effect of Task, for the recall of the distractor words, could be explained by two factors. The first possible factor is retroactive interference produced by the stem completion list. In the recall conditions, participants recalled the words from the target list, for a total of six words if they recalled the whole list. In contrast, in the stem completion conditions, participants were asked to complete a list of 24 stems, thus exposing them to 24 words. The greater number of words participants were exposed to, in the stem completion conditions, possibly produced greater retroactive interference, leading to a decrease in performance. In addition, the stem completion task led to a different focus,

and was more demanding than the recall task, possibly leading to interference and decreased recall.

Furthermore, because of the nature of the tests, participants required less time for the recall of the target list (in the Recall condition), than for the completion of the stem completion list (in the Stem Completion condition). Thus the reduced interval between presentation of the distractor lists and recall of such lists, in the Recall condition, as opposed to the Stem Completion condition, could partially account for the difference in performance.

## STEM COMPLETION OF THE FIRST SIX LISTS

As a final task, the participants were asked to complete a stem completion list. Some of the stems presented could be completed with words presented during the first six lists, the distractor lists. In particular, the first two, and the last two words, from each one of the distractor lists, could be used to fill in the stems. The number of participants that were used for this analysis was 288. The design was a 2 Task (Priming and Recency) X 2 Suffix (suffix and non-suffix) X 2 Modality (auditory and visual) X 2 Frequency (high frequency and low frequency) factorial design.

The ANOVA performed produced a main effect of Modality,  $F(1,17)= 16.32$ ,  $MSE= 227.80$ ,  $p<.0008$ . The performance of participants in the auditory conditions was better than that in the visual conditions. In the auditory conditions, the mean proportion of words from the distractor list, appropriately used to fill in the stems, was .342, while in the visual conditions, the proportion of words was .294.

These results go against the common idea that repetition priming is influenced more by the basic structure of the stimulus, such as the way the stimulus looks, as opposed to other representation, such as an auditory or semantic representation. The discrepancy between these results and other findings in the literature can be solved by looking more closely at the method of presentation used in Experiments 1 and 2. In the auditory presentation, participants were asked to read stimuli out loud that appeared on the computer screen. Thus, in reality, during the auditory presentation, participants not only heard the stimuli, but also were presented with the visual representation of it. The

better performance obtained in the auditory condition could be explained by the fact that participants in that condition, had extra information about the stimuli. Not only did they have visual information, but also their auditory information about the stimuli was likely to be stronger than for the participants in the visual condition. Thus, while performing the stem completion task, participants in the auditory condition could use visual, as well as auditory information about the stimuli to fill in the stems with one of the words previously presented in the distractor lists.

## GENERAL DISCUSSION

Baddeley and Hitch (1993), argued that priming and recency may be parts of the same implicit memory process. Even though priming and recency have never been directly compared, evidence suggests that recency may not be an implicit memory process.

Roediger and Blaxton (1987), for example, found that fragment completion priming, a test of implicit memory, was better when stimulus presentation was visual as opposed to auditory, while auditory superiority is a widely known phenomenon in recall or recognition, and is, in essence, the foundation of recency. Furthermore, the level of processing during study has little or no effect on the performance in implicit tests, while typically it does have an effect on explicit memory tests (Graf and Schacter, 1989). This evidence, together with the fact that priming typically is measured by implicit tasks, while recency is usually measured by explicit tasks, provided a challenge for the Baddeley and Hitch hypothesis.

The experiments described in this paper, by using a new paradigm, were designed to test Baddeley and Hitch (1993) hypothesis. Seven lists composed of words and numbers were presented to participants. After each one of the first six lists, participants were asked to recall the numbers presented in the previous list. After the seventh list, in the recall condition participants were asked to recall the words from that list, while participants in the stem completion condition were asked to complete a list of stem, some of which could be completed making them into words presented in list seven. The recall condition was used to measure the recency effect, and the stem completion condition to

measure the priming effect. The two effects were measured with auditory or visual presentations, and with either high or low frequency words as stimuli. This methodology allowed for a direct comparison of priming and recency, within the same condition.

In Experiment 1 a digit was presented at the end of list seven, acting as a suffix for the stimuli presented previously in the list. A 2 Task (recency, priming) X 2 Presentation (auditory, visual) X 2 Frequency (high, low) log linear analysis provided important results. The three main effects were all significant. A significant main effect of Task resulted from greater performance in the priming condition than in the recency condition. A significant main effect of Modality was produced by greater performance with auditory than with visual presentation. And a main effect of Frequency was due to better performance with low frequency words than with high frequency words. A number of Fisher Exact tests were used to determine the origin of the significant main effects, and revealed some important results. Priming was found to be significantly different between the high and low frequency auditory conditions, while recency was not. This results suggested a dissociation between priming and recency, since the two were affected in a different way by the frequency of the stimuli.

Priming was found to be greater in the low frequency condition. The low frequency advantage may be explained by the literature indicating that there is a low frequency advantage in recognition tasks (see Dennis, 1995; Schulman and Lovelace, 1970), and by the possibility that stem completion tasks may be similar to recognition tasks, because in order to complete a stem, the participant has to “recognize” the stem as

belonging to a particular word. The Fisher Exact tests performed also indicated that recency was significantly different for the auditory and visual conditions, in both the high and low frequency conditions, while priming did not differ significantly in the two presentation modalities. These results indicate another dissociation between priming and recency, since recency, as expected, occurred more often with auditory presentation, while in contrast priming did not. Furthermore the main effect of Task showed that there priming and recency were significantly different from each other when summed across all the conditions. Since both priming and recency were measured using methods that were consistent with their definitions, it is possible to argue that the significant main effect of Task is another indication of a dissociation between priming and recency.

Additionally, a significant interaction effect was found for Task (priming and recency), X Modality (auditory and visual). The levels of priming and recency were similar in the auditory condition, while there was a significant difference in the visual condition. More specifically, priming was similar for both modalities, but recency in the auditory condition was much greater than in the visual condition. The difference in the amount of recency found was expected, because of the modality effect, which is defined as the greater recall that is found when stimuli presentation is auditory rather than visual. Recency is typically found to be stronger in auditory presentation, when compared to visual presentation.

The results described are contradicted by literature suggesting that priming is increased when the physical structure of the stimulus during presentation closely resembles

the physical structure of the stimulus during a task (see Roediger and Blaxton, 1987). This apparent discrepancy stems from the fact that the stem completion task, in the current experiments, is primarily visual, since the participants are asked to fill in stems that are visually presented. Thus visual presentation of the stimuli should produce better priming than auditory presentation. However, it is important to note that in the current experiment the auditory presentation was not solely auditory, e.g., through headphones. Instead it was both auditory and visual, since the participants were asked to read the stimuli aloud, that were presented on the computer screen. This type of presentation was selected because it is typical in the recency literature, even though it is rare in the implicit memory literature. The literature has suggested that, with respect to recall, this auditory presentation with a visual component does not differ significantly from an auditory presentation without the visual component (see Crowder, 1970).

The results of Experiment 1 are a clear indication of a dissociation between priming and recency. If priming and recency were parts of the same process, they would be expected to behave in the same way across the different conditions. However, the results of the log-linear analysis and of the Fisher Exact tests, suggest that under the specific conditions of Experiment 1, recency is affected by modality of presentation while priming is not.

In Experiment 2, recall or stem completion were again used to evaluate the priming and recency effects. The two effects were again measured using auditory and visual presentations, and using high or low frequency words as stimuli. Unlike Experiment

1. in Experiment 2 there was no digit presented at the end of each target list that could potentially act as a suffix. A 2 Task (recency, priming) X 2 Modality (auditory, visual) X 2 Frequency (high, low), log-linear analysis was used, as in Experiment 1, to evaluate the results.

The three main effects were all significant. A significant main effect of Task resulted from greater performance in the priming condition than in the recency condition. A significant main effect of Modality was produced by greater performance with auditory than with visual presentation. And a main effect of Frequency was due to better performance with low frequency words than with high frequency words. Again, Fisher Exact tests were used to clarify some of the significant results. As in Experiment 1 priming was found to be sensitive to changes in the frequency of the stimuli, with low frequency stimuli leading to a significantly greater amount of priming than high frequency stimuli, in the visual conditions. On the other hand, there was no significant difference for recency in the same condition. Furthermore, other Fisher Exact tests indicated that recency was significantly affected by Modality, with auditory presentation leading to greater recency, while priming, in most cases, did not differ significantly in the two modalities. In addition, the significant main effect of Task showed that priming and recency were significantly different when summed across all conditions.

Of greater importance, a significant interaction was found for Task (priming and recency), X Frequency. More specifically, the difference in recency found between the high and the low frequency conditions was minimal, while there was a significant

difference between the level of priming found between frequencies. Priming was greater when the target words presented were low frequency words, and it decreased when the target words were high frequency words.

In order to explain these results, particular attention has to be given to the nature of the tasks being used to assess priming and recency. As previously discussed, recency was evaluated using a recall task, while priming was measured using a stem completion task. The literature on word frequency effects is not clear, and there are many conflicting findings. The general assumption is that in most cases, typically involving explicit memory, performance is better using high frequency words. For example, a number of experiments have shown that recall is better for high frequency words than for low frequency words (Gregg, 1976; Sumbly, 1963). More recently, Rajaram and Neely (1992), have found that lexical decision making is also better for high as opposed to low frequency words. However, an increasing number of research have found a low frequency advantage. In fact, a number of studies have reported that, in tests of word recognition, performance is better for low as opposed to high frequency words (Dennis, 1995; Schulman and Lovelace, 1970). A number of studies have also found a low frequency advantage in implicit memory tasks. In an experiment by Kinoshita (1995), a lexical decision task produced greater repetition priming for low frequency words when compared to high frequency words. Furthermore, Nicolas and Soderlund (2000), presented target words in the context of coherent text. A higher level of stem completion priming was found for low frequency words than for high frequency words. Thus, there appears to be some support

for the finding that low frequency words may produce greater repetition priming than high frequency words.

Another explanation of the significant interaction found in Experiment 2 may be found after a close examination of the tasks employed. Recency was measured using a recall task and was determined by calculating the difference between the number of words recalled at the end of the list and the number of words recalled in the middle of the list. The difference in recall, if any, produced by the high as opposed to the low frequency condition, would be likely to occur across all serial positions, and therefore, there would be no effect on the amount of recency measured. On the other hand, the level of priming was measured using the number of stems filled in using the target words, and was obviously measured across all serial positions. Thus, under these conditions, a word frequency effect would be likely to affect priming more than recency.

The fact that the level of priming was greater for low frequency as opposed to high frequency words can be understood by considering the similarities between stem completion and recognition tasks. As previously discussed, experimental evidence suggests that low frequency words lead to greater recognition than high frequency words. Several models have been advanced to explain this phenomenon. The first model was offered by Mandler (1980), who theorized that recognition was dependent on the relative increment in familiarity. Since high frequency words are already familiar, the relative increment in familiarity produced by their presentation would be relatively small. On the other hand, low frequency words are not as familiar, and therefore their presentation leads

to a greater increment in familiarity.

More recent explanations suggest that an attention/likelihood model may be a better explanation for the results. For example, Glanzer and Adams, (1990), as well as Glanzer, Adams and Iverson, (1991), suggested that conditions that requires greater attention, such as the presentation of low frequency words, as opposed to high frequency words, leads to a stronger “marking” of the feature vector. Subsequently, during the recognition test, the participants are able to determine if a word has been presented previously by comparing the marking of the words presented. Words with a stronger marking would mean that it is likely that they were previously presented, and since low frequency words produce stronger marking they would be more easily recognized. It could be argued that stem completion, in a repetition priming task, can be regarded as a particular kind of recognition. In this task, a word is presented, and later the subject is asked to fill in a stem, created by the first few letters of the previously presented word, by using the first appropriate word that comes to mind. If the presentation of low frequency words leads to a greater increment in familiarity, or to a stronger marking of the feature vector, then it is likely that their use in the stem completion task would be greater than the use of high frequency words.

Thus, the results provided by Experiment 2 give further support to the idea that priming and recency may be mediated by different processes, since they are affected differently by different conditions.

When Experiments 1 and 2 were combined into a single log-linear analysis, the

results confirmed what was found in Experiments 1 and 2, with several additions. There were again three significant main effects, of Task (priming and recency), Modality (auditory and visual), as well as Frequency (high and low). Additionally, there was no significant main effect of Suffix, suggesting that the digit presented at the end of the target list in Experiment 1 did not produce a suffix effect. Support for the absence of suffix effects found in this particular paradigm comes from a number of different studies. Gardiner and Gregg (1979), found no suffix effect when they instructed the participants to count backwards, before and after each stimulus to be remembered, including the last one. In addition to that, Watkins and Peynircioglu (1983), presented words of three different categories within the same list, and obtained three recency effects, so that the last word presented did not act as a suffix for the words from different categories presented before it. Thus, it appears that when information from different categories are presented as stimuli, the last stimulus presented does not produce a suffix effect in the other lists. Therefore, the studies described above may explain why suffix effects were not found in Experiment 1.

The analysis performed for Experiments 1 and 2 combined, also showed an interaction of Task X Frequency. Again, these results suggest a dissociation between priming and recency. Furthermore, there was a significant three way interaction effect of Task X Modality X Suffix. This effect was produced mainly by the finding that, as in Experiment 1, there was a large difference in recency between the auditory and the visual conditions, while for priming the difference was much less pronounced. Thus, the

combined analysis of Experiments 1 and 2 gave further evidence that priming and recency are not parts of the same process since the two effects can be dissociated.

A comparison of the results in Experiments 2 and 3 was important because information could be gained on how different levels of attention given to the stimuli affects priming and recency. The difference between the two experiments was that in Experiment 2, the attention of the participants was directed towards the digits presented in the distractor lists, while in Experiment 3, the participants attention was directed towards the words presented in the distractor lists. In Experiment 2, priming was significantly greater than recency. If the low level of recency, as compared to priming, was due to the distractor activity of having to recall the digits during the first six lists, then the difference between priming and recency should diminish by focusing the participants attention on the words. On the other hand, if the difference between priming and recency remained the same, then there would be further evidence of a dissociation between priming and recency.

The only significant effect in the log linear analysis for Experiments 2 and 3 was a main effect of Task, that is priming and recency were significantly different from each other. An interesting aspect appeared when these results were analyzed in more detail. There was no significant difference between the levels of recency found in the two experiments. Since the level of recency did not increase significantly in Experiment 3 as compared to Experiment 2, these results validate the previous ones, obtained in Experiments 1 and 2, by showing that the low level of recency, as compared to priming, was not an artifact produced by the distractors, and is a robust phenomenon.

In the analysis of the immediate and delayed recall a significant interaction of Task X Serial Position was found. Delayed recall showed greater primacy, while immediate recall showed more recency. The absence of priming in the immediate recall condition was expected, since other researchers have shown that in incidental learning tasks, where recall is a surprise, the primacy effect is greatly reduced. (see Baddeley and Hitch, 1977; Glenberg et al., 1980). More importantly, these results show that primacy is restored in delayed recall. These results fit the original view from the Modal Model (Atkinson and Shiffrin, 1968), of STM and LTM, where recency is thought to be a result of STM, and primacy is a result of LTM.

In the analysis for the delayed recall and delayed stem completion of the target list the results showed a significant interaction of Task X Frequency. Delayed recall was not affected by the frequency of the stimuli, while low frequency stimuli led to greater stem completion than high frequency stimuli. These results were consistent with the ones found in Experiments 1 and 2, where priming was significantly greater in the low frequency condition as compared to the high frequency condition, while recall was not affected by the frequency of the stimuli.

The analysis for the recall of the distractor lists showed a main effect of Condition. Participants in the recall condition were able to recall a significantly greater number of distractor words at the end of the experiment, than the participants who were in the stem completion condition. A number of factors could be responsible for these results, including retroactive interference from the stem completion list, greater attentional demands of the

stem completion task, and a longer time interval between the presentation of the distractor and recall, for participants in the stem completion condition.

The analysis for the stem completion of the distractor list revealed a main effect of Modality. Participants in the auditory condition completed significantly more stems with the words presented in the distractor list than participants in the visual condition. Reports in the literature suggest that stem completion should be affected more by basic structure information of the stimulus, rather than “deeper” information such as auditory or semantic information, therefore these results appear to be hard to explain. However, it is important to note that the auditory presentation of these experiments consisted in presenting written information on a computer screen, and instructing the participants to read it out loud, providing the auditory information. Therefore, in the auditory condition, participants had auditory as well as visual information about the stimulus. It is possible that this added information may elicit a greater activation of the representation of the stimulus, leading to greater performance in the delayed stem completion task.

In conclusion, the results of Experiments 1, Experiment 2 and Experiment 3, clearly indicate that priming and recency are not parts of the same implicit memory process, and this contradicts the view of Baddeley and Hitch (1993). Recency appear to be more sensitive to presentation modality, with better performance if the presentation is auditory as opposed to visual, while priming does not appear to be affected as much by presentation modality. In particular, there is a sharp decrease in recency when stimuli are presented visually, while there is no decrease in priming. These results were expected

since the auditory presentation is the basis for the modality effect and recency. On the other hand priming, at least when measured using a stem completion task in a repetition priming paradigm, appears to be more sensitive to changes in the frequency of the words presented. When low frequency words are used as stimuli, priming is greater than when high frequency words are used as stimuli, while recency does not appear to be affected by the frequency of the stimuli. In addition, the analysis for Experiments 2 and 3 revealed that the difference in the overall levels of priming and recency were not due to an artifact, created by the distractor activity before stimuli presentation, and that these differences remained constant even if the attention of the participants was directed towards the relevant stimuli. Therefore, since a number of dissociations have been found for priming and recency, and the method used to measure priming and recency has been proven to be adequate, it seems appropriate to derive the conclusion that priming and recency are not parts of the same implicit memory process.

APPENDIX

## APPENDIX A

Words presented in the initial six lists

MODEL	SPORT	BLIND	LEVEL	AWAKE	SCORE
SHELL	TITLE	AVOID	SPEED	EVENT	SLAVE
TOWER	CABIN	BLOCK	BLAME	NOBLE	LOCAL
ROYAL	HABIT	MORAL	TRICK	EQUAL	PROUD
ADOPT	FENCE	TROOP	GIANT	PORCH	TRAIL
BRAIN	PUPIL	FANCY	HONEY	BEAST	CLOCK

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