

## **ABSTRACT**

PETLICK, JULIE HINSON. Learning and Memory in the Visual, Auditory, and Olfactory Modalities: An Investigation of the Generality of Serial Position Effects. (Under the direction of James W. Kalat and Slater E. Newman.)

Serial position effects have been obtained in species including pigeons, monkeys, and humans. They have been demonstrated in both young and old humans and non-humans alike. The research findings have indicated that short retention intervals produce a strong recency effect whereas longer retention intervals give way to the primacy effect. This traditional recency-primacy shift is supported by a great deal of empirical research. Much of the research involves stimuli that can be classified as verbal and in most cases are presented visually. There are few investigations of the generality of primacy and recency effects at a strictly sensory level, such as with nonverbal stimuli especially in non-visual modalities. The few investigations that have been reported have obtained inconsistent findings. This experiment utilized a serial probe recognition task to investigate recognition memory for nonverbal stimuli across 5 list positions. The visual, auditory, and olfactory modalities were tested at both a 3 and 15 second delay. Results indicated the presence of both primacy and recency effects in the auditory and olfactory modalities at short delay intervals. The shift from recency to primacy was not obtained when delay was increased from 3 to 15 seconds. The data suggest that serial position effects are characteristic of memory in general; however, additional research regarding the effects of increased delay is warranted.

LEARNING AND MEMORY IN THE VISUAL, AUDITORY, AND OLFACTORY  
MODALITIES: AN INVESTIGATION OF THE GENERALITY OF SERIAL  
POSITION EFFECTS

by

Julie Hinson Petlick

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APPROVED BY

James R. Klatz

John E. Hansen

Elizabeth A. Kensler

Shardya A. Combs-Lane

Lynne Baker Ward

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## Biography

Julie Hinson Petlick obtained a B.A. in Psychology from North Carolina State University, in May of 1994. She entered graduate school in the fall of 1994 and began investigating the effects of calcium channel blocker on recovery of function. While she was taking courses in Learning Theory and in Cognition, she became interested in the serial position effect. She completed a thesis on serial position effects in aged monkey memory and received her Masters in 1997.

While in graduate school, she taught courses in Biological Psychology, Learning and Motivation, Adolescent Psychology, Introduction to Psychology, and laboratory sections of Research Methods and Statistics. She also co-taught a graduate distance education course in Using Technology for Learning. For the distance education course, she helped to design and develop a web site, and also co-wrote the content for the course. During her work on this course she developed her second research interest in the area of using technology to facilitate learning.

During her time at North Carolina State, she continued her dual interests in learning and technology and in the serial position effect. She has written tutorials and given presentations for educators to help facilitate their use of technology as well as their teaching with technology. For her dissertation, she focused on whether or not the serial position effect was a fundamental aspect of memory or if it was specific to visual and verbal material.

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## Learning and Memory in the Visual, Auditory, and Olfactory Modalities: An Investigation of the Generality of Serial Position Effects

### **Introduction**

Serial position effects are a pervasive characteristic of human memory and have had a considerable impact on the study of memory. Serial position effects (SPE's) refer to the differences in recall of items based upon location in a list. Items that occur at the beginning of a list (primacy), and items that occur at the end of a list (recency), are more likely to be recalled than items located in the middle. The U-shaped serial position function is a robust finding and is well documented in the literature. Also well documented is a recency-primacy shift when the retention interval is increased. Typically, if list memory is tested following a short retention interval, the recency effect is the more prominent effect; however, as the retention interval increases, the primacy effect becomes more prominent. SPE's and the recency-primacy shift are easily recognizable when inspecting graphed data from both recall and recognition studies.

Although SPE's have been supported by a long history of empirical research and under a variety of conditions, most research has utilized stimuli that can be classified as verbal material (e.g. words, nameable pictures and objects). It has also been the case that much of the research presented stimuli visually. SPE's and the recency-primacy shift have been reliably obtained in humans and non-human animal models. On the basis of the vast majority of the research findings, it is tempting to conclude that primacy and recency and the relationship with increasing retention intervals are fundamental characteristics of memory in general. However, recent experiments that have examined memory at a more basic sensory

level (nonverbal stimuli) either have been unable to obtain primacy and recency effects or have obtained inconsistent results. The research procedures utilized in this experiment provide an investigation of the generality of the primacy and recency effect and of the recency-primacy shift at a more basic sensory level.

### **Literature Review**

The study of serial learning was first introduced by Ebbinghaus, who began by arranging nonsense materials into serial lists and measuring the number of trials to criterion as well as savings following an imposed delay interval. Modifications of his basic methodology have allowed researchers to extend the study of memory to what it has become today. The nonsense syllable provided researchers with one of the earliest means of conducting empirical investigations of memory. One of the ways early researchers, including Ebbinghaus, studied memory was by comparing the number of trials required to learn meaningful material versus nonsense material.

One oft-cited experiment on serial position effects is that of McCrary and Hunter (1953), who used the serial anticipation method and examined rates of learning for 14 nonsense syllables versus 14 familiar names. The number of errors was plotted by list position. Bow-shaped curves were obtained for both conditions with the majority of errors occurring in the middle of the list. Although more errors occurred in the middle of the list, this tendency was considerably reduced when the stimuli were familiar names instead of nonsense syllables.

Other researchers using different methodologies also obtained similar findings regarding differences in memory based upon an item's location in a list. Murdock, Jr. (1962) presented participants with word lists of varying lengths at various presentation rates and

allowed 1 1/2 minutes for free-recall. The data were plotted as probability of recall based upon the item's serial position. Items at the beginning of the list (primacy) had a high probability of recall as did items occupying the last few positions in the list (recency). Probability of recall was poorest for items occupying the middle portion of the list. The probability curves were bow-shaped with somewhat of an S shape at the end or recency portion of the list. Murdock presented the experimental findings in conjunction with other work reported in the literature and essentially provided a detailed description of the SPE under free recall conditions. Worth noting are his concluding remarks in which he suggested a possible theoretical basis for SPE's as being due to proactive and retroactive interference.

The basic notion of interference theory is that the retrieval of information results from competition or interference among stimuli. With regard to serial lists, early list items could become confused with or displaced by the presentation of subsequent list items, which would be an example of retroactive interference (RI). Likewise, items that occur during the latter portion of the list, could be interfered with by preceding list items thus demonstrating proactive interference (PI). Since the first list item is not preceded by an item, nor is the last item followed by another item, the items presented in these positions are less susceptible to proactive interference and retroactive interference respectively. Items occupying the middle segment of the list, however, are vulnerable to both PI and RI. Due to the greater amount of interference for items in the middle portion of the list, probability of recall is lowest in the middle portion. This is one explanation as to why serial learning experiments yield bow-shaped memory curves.

Another early theoretical account of the serial position effect is the two-store theory. Glanzer and Cunitz (1966) suggested the existence of two storage mechanisms to account for

primacy and recency effects. Glanzer and Cunitz proposed that the U shaped serial position curve was actually two curves. Each curve represented output from one of two separate storage systems. Primacy was purported to derive from output from a long-term store and recency was purported to derive from output from short-term storage. To test these hypotheses, Glanzer and Cunitz conducted two experiments using free recall to see if they could manipulate variables in such a way as to impact one of the effects while leaving the other unaffected.

In the first experiment Glanzer and Cunitz manipulated the presentation rate of the list items. The lists consisted of twenty, one-syllable nouns. List items were presented via tape recordings with presentation rates of 3, 6 or 9-seconds per item. Participants were given two minutes for free recall. The results indicated that as presentation rate increased, the probability of recall was greater for items occurring early in the list whereas items occurring later in the list were unaffected.

In the second experiment, the delay between list presentation and recall was manipulated. Glanzer and Cunitz presented 15-item word lists using a slide projector and in addition the experimenter read each word aloud as it appeared. List presentation was followed by a delay interval of 0, 10, or 30-seconds. During the 10-second and 30-second delay intervals the participants counted aloud. Following the delay interval the participants were instructed to free-recall the items. The results indicated that as the delay interval increased, the probability of recall decreased for items occurring late in the list but early list items remained unaffected. The decrease in recall of the later list items was used to support the notion that recency was a function of short-term memory and therefore susceptible to temporal decay. The overall findings from the two experiments demonstrated that different

factors could affect different aspects of the curve while leaving the other portion unaffected and therefore the results supported the two-storage theory.

The research and the theoretical account of Murdock, Jr. (1962) and Glanzer and Cunitz (1966) represent some of the early work regarding verbal memory and the serial position effect. Their research demonstrates the existence of the primacy effect and the recency effect using the method of free recall. Furthermore, Glanzer and Cunitz's research demonstrates that primacy and recency can be obtained using verbal stimuli presented aurally (Experiment 1). In addition, the results of Experiment 2 also demonstrate the relationship between increasing retention interval and the recency effect (i.e. the recency-primacy shift).

Since that time, verbal memory and the SPE have received considerable attention. Indeed, numerous experiments have obtained primacy and recency effects using verbal material under a wide variety of different conditions establishing the robustness of the SPE (e.g., Sands & Wright, 1980b; Roberts & Kraemer, 1981; Brown & Brown, 1982; Wright, Santiago, Sands, Kendrick & Cook, 1985; Korsnes & Gilinsky, 1993; Neath & Knodler, 1994). SPE's have been found for both recall and recognition of items. They have been demonstrated using free recall, and serial probe recognition methodologies. Some variables that have been shown to affect SPE's are retention interval (Wright, et al., 1985), semantic category (Cole, Frankel & Sharp, 1971), age (Korsnes & Gilinsky, 1993) and dementia (Massman, Delis & Butters, 1993). Thus, the data would seem to suggest that SPE's are a consistent characteristic of human memory in general.

The prominence of SPE's in memory affords them the utility of being used as a benchmark for memory comparisons. For example, some investigators use SPE's to study memory development and change across the lifespan (Cole, Frankel & Sharp, 1971; Moss,

Rosene & Peters, 1988; Korsnes & Gilinsky, 1993). One example of such research is an experiment in which Massman, Delis, and Butters (1993) compared the serial position curves for individuals with Huntington's disease (HD) and Alzheimer's disease (AD) with that of normal age-matched controls to investigate memory differences. Participants were orally presented with a 16-item word list (list A) for five trials. The list consisted of four categories (fruit, spices, clothing, and tools) each containing four items. Items from the same category were not adjacent to one another. Following each trial the participant was allowed free recall. An interference list (list B) was orally presented after the fifth trial followed by free recall. Twenty minutes later, a free recall test, category cued recall test, and a yes/no recognition test containing the 16 list items along with 28 distracters was administered for the original list (list A).

The HD and AD groups had impaired performance on the primacy portion of the list compared to the normal age-matched controls on tests of immediate free recall, category cued recall, and delayed recall. However, on the recognition test, the HD participants did not differ significantly from normal age-matched controls on the primacy portion but the AD participants scored significantly worse. The HD and AD both showed immediate free recall for recency items equivalent to that of the normal age-matched controls. As testing progressed from trial one to trial five, the AD participants performed significantly worse than the controls. Both the HD and AD participants performed worse than their matched counterparts on the delayed recall and recognition tests for recency items.

While some researchers have used SPE's to investigate memory changes related to different dementias, animal researchers have used SPE's to investigate similarities between human and non-human memory. Sands & Wright (1980a) compared the serial probe

recognition (SPR) performance of a 4-year old rhesus monkey with that of an adult human (22 years) on the same task. Ten-item lists were used which consisted of photographs of common objects such as fruits and flowers. Items (photographs) were displayed onto a screen using a projector, for 1-second each, and separated by 0.8-second delay. A 1-second delay interval was used followed by presentation of a single probe item. The participant responded by pressing a lever to the right to indicate if the item was the same as one of the list items and to the left to indicate if the item was different from the list items. Primacy and recency effects were obtained for both the rhesus and human.

Sands & Wright (1980b) conducted two additional experiments comparing human and monkey memory. Experiment one was a replication of their earlier research (1980a) in which they tested a monkey and a human using a 10-item list followed by a 1-second delay interval. Experiment two extended the research by lengthening the list to include 20-items. Once again the results indicated the presence of primacy and recency effects. These findings provide further support for the pervasiveness of primacy and recency effects. Sands and Wright's findings not only demonstrate that primacy and recency effects are characteristic of both human and monkey memory, but they also demonstrate that primacy and recency effects can be obtained using a serial probe recognition task and can be obtained with stimuli which consist of photographs of common objects.

Numerous additional experiments have since demonstrated primacy and recency effects in many species including pigeons (Wright et al, 1985), squirrel monkeys (Roberts & Kraemer, 1981), and rhesus monkeys (Castro & Larsen, 1992) providing further empirical evidence that primacy and recency effects are characteristic of memory in general. In addition to the research demonstrating primacy and recency under a variety of conditions

across species, other research has presented evidence suggesting that the recency-primacy shift might also be a general memory characteristic.

Glanzer and Cunitz (1966) found decreasing recency effects when the delay interval between list presentation and test was increased. Korsnes and Gilinsky (1993) presented groups of younger (aged 25-35, M=27 years.) and older (aged 65-75, M=71.6 years.) adults with 4-item lists followed by a delay interval of 1, 50, or 100-seconds. A serial probe recognition task was used to compare the memory performance of younger and older adults. The recency effect was most prominent at the lowest delay interval and gave way to a primacy effect as the delay interval was increased. Most noticeable was the finding that older adults experienced the shift from recency to primacy earlier than young participants when delay was increased.

Wright et al. (1985) tested pigeons, monkeys and humans using a serial probe recognition task. Four-item lists were used in conjunction with varying delay intervals to compare memory performance on serial lists across the three species. Delay intervals ranged from 0 seconds up to 100 seconds. The results indicated the presence of a strong recency effect at the lower delay intervals and a primacy effect at the longer delay intervals. The shift from recency to primacy occurred for all three species. An interesting finding, one that is also similar to that found by Korsnes and Gilinsky (1993), was that the three species differed in the amount of increase necessary to bring about the shift. Pigeons required the least amount of increase prior to shifting and humans required the largest increase prior to shifting. The reported findings provide empirical support for the traditional recency-primacy shift as being characteristic of memory for species including pigeons, monkeys, young and older humans.

Although SPE's have been reliably obtained under a wide range of conditions, the research has been dominated by the use of verbal material. For humans, the visual stimuli are often words and occasionally images (pictures) (Neath & Knoedler, 1994). For experiments involving animals, the visual stimuli have often been pictures (Castro & Larsen, 1992). SPE's for nonverbal and non-visual stimuli have not been as thoroughly investigated. The auditory, olfactory and tactile modalities have been largely overlooked with respect to SPE's and using nonverbal stimuli would allow these modalities to be investigated. Due to the lack of research in these other modalities, there is currently not sufficient evidence as to whether SPE's are characteristic of memory in general or whether they are specific to verbal material. At present the most that can be said with any certainty is that they are characteristic of verbal material and of the visual modality.

#### *Theoretical Basis of SPE's*

Much like the way in which verbal stimuli have dominated the study of the serial position effect, complex mathematical models that are somewhat narrow in focus dominate contemporary theories of SPE's. For example, Farrell and Lewandowsky (2002) propose the SOB (serial-order-in-a-box) model of ordering in serial recall. The model describes a network architecture that involves a "weight matrix." Vectors of features represent each item, and the weight matrix consists of these vectors. List items and the connections among them (their features) are what make up the model. Retrieval is based upon nonlinear iterative dynamics in which the vector of an item must fall within a "basin of attraction" (Farrell & Lewandowsky, 2002). The complexity of the model makes its application by researchers outside the field of network modeling difficult at best. In addition to the complexity of the

mathematical modeling, the underlying principles of the theory are also not generalizable to serial probe recognition tasks.

The basic premise of the theory rests on two assumptions, a primacy gradient and response suppression. The primacy gradient assumption asserts that retrieval of an item decreases across list position, because of a decline in attention or due to a rehearsal trade-off, both reflecting strategies useful for recalling early list items (Farrell & Lewandowsky, 2002). This assumption is often represented in theoretical models by using weighting parameters that are reduced for items occurring later in the list. The primacy gradient is used to account for superior recall of initial list items compared to list items occurring in the middle portions of the list.

Response suppression is the assumption that after an item is recalled, it becomes temporarily suppressed and no longer available for recall. This assumption is necessary to explain recency effects. According to Farrell and Lewandowsky (2002), “as more and more items are recalled - and hence suppressed – fewer response alternatives remain.” The reason fewer response alternatives remain is that once an item is recalled it is suppressed, and therefore, response suppression explains why performance is higher at the end of the list compared to the middle (i.e. recency effects).

In a serial probe recognition task, such as the one utilized in the current experiment, response suppression cannot be used to account for recency effects. On a given trial, a list is presented and memory for only one list position is tested by using two probes, one of which is a new novel cue and the other a repeated list item. On the next trial, a different list is presented and memory for a different list position is tested. In addition, the positions are not tested in consecutive order. Since only one item is ever reported on a given trial, no response

suppression can occur on that trial, and therefore, response suppression cannot account for why recognition is better for items occurring at the end of the list (recency) compared to items occurring in the middle of the list.

It is possible that superior recognition of items occurring early in the list (primacy) is due to decreased attention during list presentation of later items. Therefore, the primacy gradient, as presented in Farrell and Lewandowsky's SOB model, could be used to explain primacy effects. However, the SOB model relies on the primacy gradient and response suppression, as well as the interplay between the two, to be a useful model. For these reasons, the SOB model is not applicable to the serial probe recognition paradigm used in this experiment.

There are some important differences between serial recall and serial probe recognition worth noting. The delay between learning and recall may not have the same influence in serial recall as it does in serial probe recognition. For example, in a serial recall task the participant is required to recall list items in their original order. If a 5-item list of words were presented at a rate of 1 word per second followed by a 3-second delay, then 7-seconds would pass before recall of item 1. Assuming the participant recalls the items at a rate of 1 item per second; 7-seconds would also pass between learning item 5 and recall of item 5. The delay between learning an item and recall is essentially constant for all items.

This is not the case in a serial probe recognition paradigm (SPR). In a SPR task, after presentation of list items, a delay ensues followed by a probe item. The participant must indicate if the probe item was also a list item for that trial (two-choice forced alternative) or is new. On each trial only one serial position is tested. So for a 5-item list with a presentation rate of 1 item per second and a 3-second delay, if the probe item were from the

last list position (position #5) then only 3 seconds would have elapsed between learning and recognition. However, if the probe item were for list position one, 7-seconds would have elapsed between learning and recognition. Since the temporal nature of the two tasks differs, only serial learning theories that incorporate values that reflect temporal differences would be applicable to both serial recall and serial recognition tasks.

A recent serial learning theory that incorporates temporal values is the dimensional distinctiveness model (Neath, 1993a). The basic premise of this theory is that list stimuli vary with regard to their distinctiveness along a temporal dimension. Calculation of an item's distinctiveness includes the item's position in the list, the inter-item presentation (IPI), and the retention interval. Since this theory takes such variables into account, it is more accommodating or generalizable than the SOB model. However, much like other serial learning theories, this theory also involves numerous equations and calculations that likely limit its application by researchers outside of modeling. This theory has proved useful for serial probe recognition experiments.

Neath and Knoedler (1994) used the theory to make predictions regarding serial position curves obtained from using a SPR task. Four-item lists comprised of images of snowflakes were presented to participants at a rate (IPI) of 1-second each. Following presentation of the last item in the list was a retention interval of 0, 2, or 5-seconds. A probe item was displayed after the retention interval and participants indicated if the probe snowflake was "old" or "new".

Recognition was better for items occurring at the beginning and end of the list (primacy and recency). As retention interval increased, there was a shift from recency to primacy. The model accurately predicted the results and accounted for 85% of the variance.

Although using a model to make predictions regarding serial recognition is beyond the scope of this experiment, once more data regarding the generality of serial position effects are available; the dimensional distinctiveness model might provide a useful theoretical framework from which one could continue exploration.

#### *Auditory and Olfactory SPE's*

Within the contents of this literature review, an assortment of experiments has been presented to both indicate the robustness of the serial position effect and to represent the dominance of the utilization of verbal stimuli. It is undeniable that primacy and recency are characteristic aspects of memory for verbal stimuli. Experiments with young and aged humans and non-human animal models have yielded the well-known U-shaped serial position curve. Since SPE's are representative of verbal memory for much of the lifespan and across species, it is tempting to generalize them to all aspects of memory. However, one must resist this temptation until experimental methods have yielded such findings. Memory within the olfactory and auditory modalities has largely been overlooked with regard to uncovering fundamental characteristics of memory. The few undertakings have yielded findings that are inconsistent and not indicative of the true nature of memory within these modalities.

Two recent experiments, Wright (1998) and Knoedler, Hellwig and Neath (1999), have investigated serial position effects in the auditory modality. One of the experiments used rhesus monkeys and the other used human participants. The results from the two experiments are not in agreement.

Wright (1998) tested the auditory memory of two rhesus monkeys. The monkeys were tested using a list of 4 sounds played for 2-seconds each and followed by a retention

interval of either 0, 1, 10, or 20-seconds. After the retention interval, a probe sound was played and the animal responded by touching one of two speakers to indicate whether the probe sound was one of the list items (same) or a new item (different). Primacy and recency effects were obtained; however, the primacy effect was most prominent at the short delay, and as the delay increased the recency effect became the more prominent. Although SPE's were obtained, they are opposite of what is typically found with increasing the retention interval. Wright was cautious in his conclusions but noted that the data he obtained indicated that visual and auditory serial position functions for monkeys are in opposition to one another. In the visual modality for both humans and non-humans, typically, the recency effect is most noticeable at short delays whereas the primacy effect generally becomes more prevalent with increasing delays. (Glanzer & Cunitz, 1966; Wright et al., 1985; Korsnes & Gilinsky, 1993)

With knowledge of Wright's findings, Knoedler et al. (1999) conducted an experiment using human participants to investigate the shift from recency to primacy when delay interval is increased. They conducted several experiments, one of which tested the auditory modality. In the first two experiments, Knoedler et al. (1999) presented visual stimuli consisting of a mixture of pictures and words. Four visual stimuli were presented one at a time during the study trial. During the probe test trial, the stimulus was also a picture or word. The investigators were testing to see if changing the physical form of a stimulus from study to test would affect recall. They found that performance was more accurate when the physical form of the stimulus matched from study trial to test trial. They also found that for short delays recall was better for items that occurred at the end of the list (recency) and as the delay increased, performance was more accurate for items from the beginning of the list

(primacy). These results demonstrate the typical serial position effect that is normally obtained from tests of visual memory.

For experiment three, Knoedler et al. (1999) used the same procedure as described above with the addition of having each participant pronounce the words out loud as they were presented on screen. The retention intervals tested were 1 and 3-seconds. The results indicated an interaction between serial position and retention interval. They concluded that when people were tested within the auditory modality, the recency effect is present at short delays and the primacy effect becomes more prominent at longer delays. These results are congruent with the typical recency-primacy shift and contrary to the results obtained by Wright (1998).

In Knoedler et al's procedure, there are two possible reasons as to why the investigators might have found the typical recency-primacy shift. The most obvious is that Knoedler et al. were testing humans rather than monkeys. This explanation is not likely given the fact that the animal data for serial position effects for visual stimuli directly parallel those from humans. A second and more likely explanation is based on the differences inherent in the methodologies of the two experiments. Wright (1998) used sounds as the stimuli. Knoedler et al. (1999) in experiment three presented stimuli (words) visually and the participants had to say the word aloud. One reason the results might be different from Wright's, and instead more in line with what is typical of visual memory, is that the participants could have relied on the visual stimulus (seeing the word) since it was also present during the task. It is also the case that Knoedler et al's stimuli were verbal and Wright's stimuli were nonverbal.

One of the objectives of the current experiment was to investigate whether serial position effects could be obtained using solely auditory presentation of nonverbal stimuli. In addition, if SPE's were obtained, what effect would increasing retention interval have on the shape of the serial position curves? If SPE's are characteristic of memory in general, then one would predict that items presented aurally would have a higher rate of recall if they occupied the first and last list positions. One would also expect a shift from recency to primacy to occur as retention interval is increased.

In comparison to the visual modality, the olfactory modality has received little attention with regard to serial memory processes. One of the reasons for this is the complexity of testing within this modality. People habituate after prolonged exposure to an odor. Also, various odors can linger and mix with one another and therefore contaminate the testing environment. Testing within this modality is limited by these factors that do not apply in other modalities. Due to these limitations, if testing for serial position effects within the olfactory modality, any list would need to be relatively small in size and delay intervals both between item presentation and list presentation would need to be sufficient to prevent habituation or contamination. Much like the data regarding audition, there are contradictory results that have been reported regarding serial position effects within the olfactory modality (White & Treisman, 1997; Reed, 2000).

White and Treisman (1997) conducted an experiment in which participants were presented with a list consisting of five odors. Odors were presented for 500ms followed by 2750ms of fresh air. A pair of 500 Hz tones was presented 2750ms after presentation of the last odor. Subsequent to the tones three probe odors were presented, each separated by the

500 Hz tone pair. The participants' task was to indicate whether the probes were included in the list or were new. The results obtained indicated a recency effect but no primacy effect.

Reed (2000) conducted several experiments concerning serial position effects for olfactory memory. Noting the failure to obtain primacy by White and Treisman, and the possibility of odors interfering with each other, Reed modified the methodology used by White and Treisman. Rather than presenting three probes, Reed presented two probe odors, one of which was from the list, and the other a new odor. For the first experiment, Reed presented participants with five odors, each odor exposure lasting 3-seconds with a 2-second delay interval between the odors. After the five odors were presented, a 3-second retention interval ensued followed by presentation of the two probe odors. The participants were to select the odor that had been contained within the list. Results indicated both primacy and recency effects were present.

For experiment two, Reed tested participants on lists containing seven odors. In addition, participants were divided into two groups with one group being tested using the 3-second retention interval (as in experiment one) and the second group tested using a 30-second retention interval. At a 3-second retention interval both primacy and recency effects were present. This finding is consistent with the findings of experiment one, and in addition demonstrates that SPE's can be obtained with lists as long as seven olfactory items. However, at the 30-second retention interval there was no difference in performance across any of the list positions.

Reed's findings provide some indication that SPE's may be characteristic of memory in general rather than specific to the visual modality or to verbal material. Although Reed was able to demonstrate that SPE's can be obtained within the olfactory modality, the typical

shift from recency to primacy with increasing delays was not obtained. In keeping with the objectives stated regarding the auditory modality, the current experiment additionally investigated whether SPE's would be obtained in the olfactory modality. And of additional interest, if SPE's were obtained, what effect would increasing retention interval have on the shape of the serial position curves?

In summary, there is much research reporting SPE's under various conditions within the visual modality and for verbal material. There are fewer results regarding SPE's in the auditory (nonverbal) and olfactory modalities. The auditory and olfactory research findings that are reported are contradictory and do not provide a basis for determining whether SPE's are characteristic of memory in general or whether they are specific to visual memory and verbal material. The present research presented human participants with visual, auditory, and olfactory lists comprised of non-verbal stimuli. In addition, performance was tested under two different retention intervals to determine whether or not SPE's would be obtained and what changes, if any, occurred as a result of an increased retention interval.

## **Method**

### **Participants**

Ninety-six students enrolled in an Introductory Psychology course at North Carolina State University served as participants in partial fulfillment of their course requirements. Participants ranged in age from 18 – 26 years ( $M=19.28$  years). The 3-second delay condition contained 30 males and 18 females, as did the 15-second delay condition. Each participant engaged in list learning tasks that were distributed across three modalities: visual, auditory, and olfactory. All participants reported (self report) having normal visual, auditory,

and olfactory abilities (or corrected to normal by eyewear). All participants were non-smokers.

### **Apparatus & Materials**

A Windows/Intel computer with Flash version 5.0 was used to control presentation of visual and auditory stimuli. Visual stimuli were displayed on a 15” monitor, and auditory stimuli were delivered via Sennheiser closed-back noise-reducing headphones. Olfactory stimuli were manually presented in 2” black plastic vials. Each vial had identical white labels with numbers indicating the particular stimulus. The olfactory stimuli were kept behind a screen and at no time did participants view them.

The olfactory stimuli consisted of a pool of commercially available odors purchased from The Body Shop (Appendix A). During presentation of olfactory stimuli, participants sat facing a computer monitor displaying a white screen, while the experimenter sat beside the participant but facing perpendicular. A table containing a screen was placed behind the participant, and the olfactory stimuli were placed behind the screen. During presentation of olfactory stimuli the experimenter would reach behind the screen and manually place the vial of odor directly under the participant’s nose for three- seconds.

The visual stimuli consisted of 10 snowflakes (Appendix B). Six hundred sixty-two snowflakes were obtained from Ian Neath, Purdue University (see Neath & Knoedler, 1994) and a pilot test was conducted to ensure selection of stimuli judged to be discriminable from one another (see Appendix I & J).

Auditory stimuli consisted of 10 tones (see Appendix C) created using Test-Tone Generator version 3.3 software (Esser, 2002). Tones ranged from 75 hz – 559 hz and starting from 75 hz tones were increased by a factor of .25.

## **Procedure**

### Research Design

The experimental methodology was derived from the olfactory research conducted by Reed (2000). A mixed design was utilized in which performance for two groups of participants was compared across three modalities. Participants in Groups One and Two were tested across three modalities (visual, auditory, olfactory) using retention intervals of 3 and 15 seconds respectively.

Participants were tested individually across two blocks for a total of 30 trials, 10 within each modality. Blocks were separated by a two-minute rest period. For each block of trials, each stimulus appeared a total of 7 times, once serving in each of the 5 list positions and twice serving as probes. The order in which participants were tested across modalities was balanced (Figure 1). Although the order of testing was balanced, the order in which participants were assigned to treatment conditions was quasi-random. The overall goal was to obtain a similar ratio of males and females in each treatment.



Appendix D). Participants were instructed to direct a table fan so that it was blowing directly onto their face and to put on the pair of headphones. Participants were next given the instructions regarding the task (see Appendix E).

When the participant indicated readiness to begin, the experimenter initiated the trial by double clicking the correct HTML file. The word “START” was displayed on the screen for 3-seconds followed 2-seconds later by sequential presentation of the visual stimuli (snowflakes). Each stimulus was presented for 3-seconds with a 3-second inter-stimulus interval (ISI) occurring between list items. Following the last list item, a retention interval of 3 or 15-seconds ensued. During the retention interval, 1-second after the last item, a red light was displayed for ½ -second signaling the end of the learning phase and the beginning of the test phase. Following the retention interval, probe #1 was displayed for 3-seconds followed 3-seconds later by probe #2 (see Appendix F).

The task for the participant was to indicate orally, which one of the probe items had also been presented as a list item for that trial. Participants were instructed to indicate their response by saying aloud either “probe 1” or “probe 2.” Additionally, participants were instructed to wait and respond only after both probes had been presented (see Appendix E). During block one, participants were tested for 5 visual trials. Each of the 5 list positions was tested once across the trials. A 1-minute inter-trial interval (ITI) was used to separate the trials. In creating the computer files for presentation of visual stimuli, a random numbers table was used to determine the order in which list positions were tested.

#### Auditory Modality Procedure

The auditory procedure was the same as described for the visual modality with the only modification being that tones were used as list stimuli rather than snowflakes (see

Appendix F). Participants were read the same instructions as given in the visual procedure with the word “tones” substituted in place of the word “images.” Participants were further instructed that although this was an auditory task they should remain focused on the screen because the word “START” would still appear, as would the labels “Probe 1” and “Probe 2” in conjunction with the tones (see Appendix G).

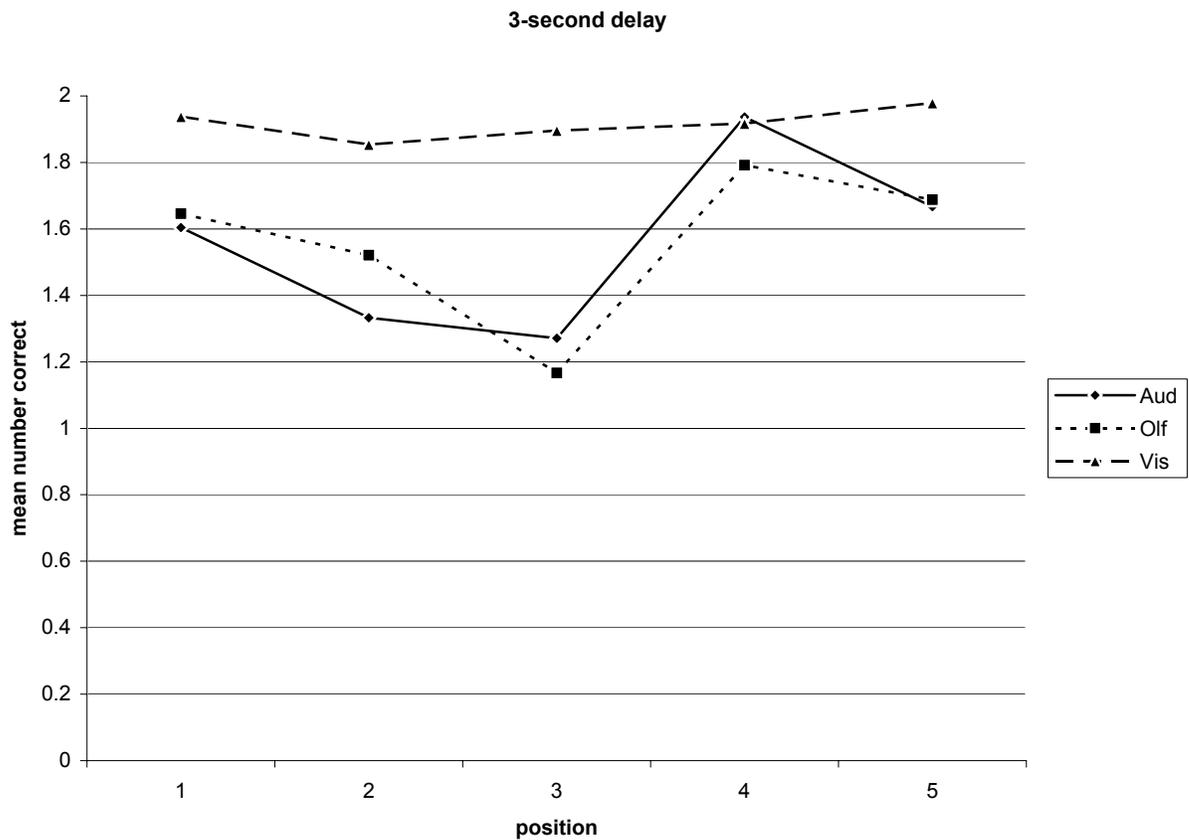
#### Olfactory Modality Procedure

The olfactory procedure followed the same design as that of the visual and auditory modalities (see Appendix H for participant instructions). A few minor differences resulted from the task being manual rather than automated. The participant sat facing the monitor that displayed a white screen. The experimenter sat beside the participant but faced perpendicular. Odors were contained in 2” black plastic vials. In the visual and auditory tasks a trial began when the word “START” was displayed on screen. In the olfactory procedure the experimenter said aloud the word “START.” Odors were manually presented and placed directly underneath a participant’s nose for approximately 2-3 seconds each. An ISI of 3 seconds occurred between the odors. Following presentation of all five odors a delay ensued followed by presentation of probe odors. During presentation of probe 1 the experimenter said aloud “Probe 1” and three seconds later said “Probe 2” during its presentation. The olfactory procedure was the same as the visual and auditory procedures except that the presentation was manual, and the words “START, Probe 1 and Probe 2” were spoken rather than displayed on the screen (see Appendix F).

## Results

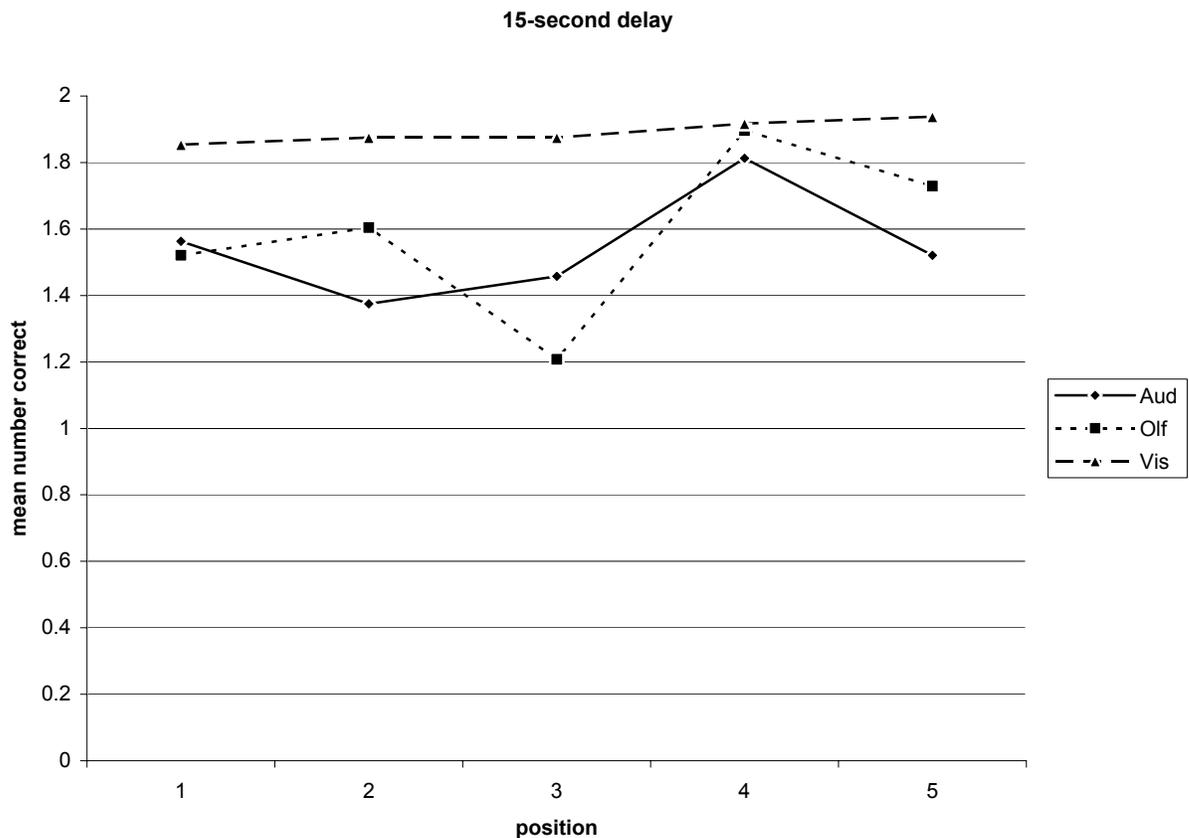
### *Overall Analysis*

Accuracy of recognition was analyzed using a 5 (position) by 3 (modality) by 2 (delay) mixed factorial ANOVA with repeated measures on two factors (modality & position). There was a main effect of position [ $F(4, 376) = 30.13, p < .0001$ ], of modality [ $F(2, 188) = 64.95, p < .0001$ ], and an interaction between modality and position [ $F(8, 752) = 8.40, p < .0001$ ]. No other effects were found to be significant ( $p > .05$ ).



**Figure 2. Mean correct for each modality across list position with 3-second delay**

Figure 2 depicts the mean number correct for recognition at each of the list positions for each modality following a delay interval of 3-seconds. Figure 3 depicts the mean number correct at each list position following a delay interval of 15-seconds.



**Figure 3. Mean correct for each modality across list position with 15-second delay**

Notice in both figures that performance on auditory and olfactory recognition varies across list position, but visual recognition performance on all five positions is close to perfect and the line is essentially flat suggesting a ceiling effect. The visual task was apparently too easy and therefore did not provide a sensitive enough measure to detect any effects of position on recognition. For that reason, the visual data were dropped and a series of separate analyses

was conducted to determine whether primacy and recency effects occurred in the auditory and olfactory conditions for each delay interval.

***Analysis for Auditory and Olfactory Conditions***

Individual analyses were conducted on the data for each modality at each delay interval in conjunction with post-hoc tests. A one-way repeated measures ANOVA was conducted on the auditory data at the 3-second delay (see Table 1). Recognition was not equal across list positions [ $F(4,188) = 12.42, p < .0001$ ].

**Table 1. ANOVA summary table for auditory performance as a function of list position for a 3-second delay interval**

Source	DF	SS	MS	F	P > F
Model	51	28.22083333	.55334967		
W/I subj	47	14.26250000	.30345745		
Treatment	4	13.95833333	3.48958333	12.42	<.0001
Error	188	52.84166667	.28107270		

A post-hoc test (Tukey) indicated that recognition was significantly higher at the beginning and end of the list compared to the middle (results are depicted in Figure 2). Performance at positions 4 & 5 was not significantly different from one another but position 4 performance was significantly higher than performance at the remaining three positions. Likewise, performance at positions 1 and 5 did not differ from one another but position 5 was significant compared to positions 2 and 3. Also, performance at positions 1 and 2 was not significantly different but position 1 performance was significantly higher than position 3. Overall, the results indicate that recognition was highest at the beginning and end of the list

and lowest in the middle of the list (see Table 2). These findings suggest that primacy and recency are obtainable in the auditory modality when nonverbal stimuli are used.

**Table 2. Tukey post-hoc test for auditory performance as a function of list position for a 3-second delay interval**

Tukey Grouping	Mean	N	Position
A	1.9375	48	4
A			
B A	1.6667	48	5
B			
B C	1.6042	48	1
C			
D C	1.3333	48	2
D			
D	1.2708	48	3

Note: means with the same letter are not significantly different

An additional one-way repeated measures ANOVA was conducted for the auditory data at the 15-second delay (see Table 3). Recognition was significantly different across list positions [ $F(4,188) = 4.58, p < .0015$ ].

**Table 3. ANOVA summary table for auditory performance as a function of list position for a 15-second delay interval**

Source	DF	SS	MS	F	P > F
Model	51	21.92083333	.42982026		
W/I subj	47	16.69583333	.35523050		
Treatment	4	5.22500000	1.30625000	4.58	<.0015
Error	188	53.57500000	.28497340		

A post-hoc test (Tukey) indicated that recognition was significantly higher at position 4 compared to positions 2 and 3. Recognition at positions 1, 4 and 5 did not differ from one another. However, recognition at positions 1 and 5 also did not differ from recognition at positions 2 and 3 (see Table 4).

**Table 4. Tukey post-hoc test for auditory performance as a function of list position for a 15-second delay interval**

Tukey Grouping	Mean	N	Position
A	1.8125	48	4
A			
B A	1.5625	48	1
B A			
B A	1.5208	48	5
B			
B	1.4583	48	3
B			
B	1.3750	48	2

Note: means with the same letter are not significantly different

A one-way repeated measures ANOVA was used to analyze recognition across list position for the olfactory data at a delay interval of 3 seconds (see Table 5). Recognition was significantly different as a function of list position [ $F(4,188) = 9.41, p < .0001$ ].

**Table 5. ANOVA summary table for olfactory performance as a function of list position for a 3-second delay interval**

Source	DF	SS	MS	F	P > F
Model	51	45.0708333	.8837418		
W/I subj	47	33.86250000	.72047872		
Treatment	4	11.20833333	2.80208333	9.41	<.0001
Error	188	55.9916667	.2978280		

A post-hoc test (Tukey) indicated recognition was equivalent at positions 1, 2, 4, and 5, but was significantly greater than recognition at position 3 (see Table 6).

**Table 6. Tukey post-hoc test for olfactory performance as a function of list position for a 3-second delay interval**

Tukey Grouping	Mean	N	Position
A	1.7917	48	4
A			
A	1.6875	48	5
A			
A	1.6458	48	1
A			
A	1.5208	48	2
B	1.1667	48	3

Note: means with the same letter are not significantly different

An additional one-way repeated measures ANOVA was used to analyze recognition across list position for olfaction at a delay interval of 15 seconds (see Table 7).

**Table 7. ANOVA summary table for olfactory performance as a function of list position for a 15-second delay interval**

Source	DF	SS	MS	F	P > F
Model	51	25.43333333	.49869281		
W/I subj	47	12.78333333	.27198582		
Treatment	4	12.65000000	3.16250000	11.76	<.0001
Error	188	50.55000000	.26888298		

Recognition was significantly different with regard to list position [ $F(4, 188) = 11.76, p < .0001$ ]. A post-hoc test (Tukey) indicated recognition at position 4 was significantly higher than all other positions except position 5. Recognition at positions 1, 2, 4 and 5 were all significantly greater than recognition at position 3 (see Table 8).

**Table 8. Tukey post-hoc test for olfactory performance as a function of list position for a 15-second delay interval**

Tukey Grouping	Mean	N	Position
A	1.8958	48	4
B A	1.7292	48	5
B	1.6042	48	2
B	1.5208	48	1
C	1.2083	48	3

Note: means with the same letter are not significantly different

### ***Summary of Results***

Overall the results indicate that primacy and recency effects are obtainable when testing in the auditory modality. At the 3-second delay, both primacy and recency effects were present. There was no shift from recency to primacy as delay interval was increased. In fact, at the 15-second delay interval, the primacy effect was no longer present. There was some evidence of a recency effect at the 15-second delay due to superior performance at position 4; however, performance at position 5 (which would be the most recent list position presented prior to testing) was not significantly different from performance in the middle of the list (position 3).

Olfactory results indicate that primacy and recency effects were present at both the 3-second and 15-second delay intervals. However, there was no evidence of a shift from recency to primacy with increased delay interval.

The visual results indicate that performance was at or near a ceiling effect in both the 3-second and 15-second delay interval conditions. No differences were found in performance across any of the positions at either delay.

## **Discussion**

### ***Overall findings***

This experiment examined the generality of serial position effects. Performance across list positions was tested in three modalities and the overall findings extend the generality of the serial position effect. Although both primacy and recency effects have been obtained with visually presented verbal material, results for other modalities using nonverbal stimuli have been inconsistent at best. The data obtained in this experiment indicate the presence of primacy and recency effects in both the auditory and olfactory modalities. A general discussion of the findings is presented for each modality, followed by a separate discussion regarding the recency-primacy shift.

### ***Discussion of Auditory Findings***

Although Knoedler et al. (1999) reported primacy and recency effects within the auditory modality, their stimuli were verbal in nature and the visual stimuli were also present. The current experiment provides a more rigorous test of auditory memory in that the stimuli were nonverbal and no corresponding visual stimuli were present during the auditory test. Using auditory nonverbal stimuli did result in recognition being best for stimuli presented at both the beginning and end of the list. This suggests that primacy and recency are indeed obtainable in auditory memory.

However, this finding was only obtained for data collected using a 3-second delay interval. At the 15-second delay interval, performance was significantly higher at position 4

compared to all other positions, which is suggestive of a recency effect. However, performance at all other positions was equivalent. Position 5 represents the position that would be most recent prior to testing. Therefore, before concluding that the recency effect is obtainable at a 15-second delay, one must determine why performance for position 4 was superior and performance for position 5 was no different than performance in the middle or beginning of the list.

One possibility is that the finding represents an artifact. A random numbers table was used in the creation of the sequences for presenting stimuli. Each list position was tested twice (once in each block) for each modality. On one of the two auditory trials for which list position 4 was being tested, the stimuli that served as probes happened to be at the two ends of the range. One of the probes for the trial was 75 Hz and the other probe was 559 Hz. The correct probe (the one that was also presented within the list) was the 75 Hz tone. Since the 559 Hz tone did not occur during the trial, it might have been more distinctive in the context of the trial, and therefore, could have been easier to rule out as the correct response, thereby elevating performance at that position. Further research within the auditory modality is clearly needed before one can state with any certainty that SPE's are present at long delay intervals.

### ***Discussion of Olfactory Findings***

Primacy and recency effects were present at both the 3-second and 15-second delay intervals. In fact, regardless of delay interval, performance was better at the beginning and end of the list compared to the middle portion. The data for the 3-second delay are also consistent with Reed's (2000) finding of primacy and recency in the olfactory modality, and thus provide additional support for serial position effects being characteristic of olfactory

memory. Although Reed was unable to obtain serial position effects using a delay of 30-seconds, the present findings demonstrate primacy and recency can be obtained using a delay interval of 15-seconds.

### ***Discussion of Visual Findings***

The data for visual recognition were disappointing and uninformative with regard to the hypothesis of interest due to an unexpected ceiling effect. A pilot study suggested that the list length, presentation rate, ISI and retention interval could have been appropriate to detect deficits in recognition (see Appendix K & L). However, the pilot study was conducted using classroom populations in a group setting that may have had various sources of interference. During the actual experiment, individuals were tested individually in a controlled environment and this could have facilitated performance.

Although the visual data were disappointing with regard to serial position effects, information collected during debriefing provided some feedback regarding their appropriateness as nonverbal stimuli. The visual stimuli were snowflakes, which were obtained from Ian Neath, Purdue University. Neath utilized these snowflake stimuli in several experiments (Knoedler et al. (1999); Neath, & Knoedler, 1994). The protocols used by Neath were such that the stimuli were selected for presentation on a random basis.

For the current experiment a pilot experiment was conducted to ensure that participants could reliably discriminate each of the snowflakes from all of the others (see Appendix I & J). The pilot study was done to rule out the possibility of recognition failures being due to participants' inability to discriminate rather than to their not being able to remember. Although ensuring that stimuli can be discriminated from one another was a worthwhile endeavor and provided a stringent test of memory, it inadvertently may have

helped facilitate performance. As can be seen from inspecting the data, visual performance was at or near a ceiling effect.

Of more interest, was that it was also the case that during the current experiment, participants all reported naming the snowflakes. During debriefing, all participants were asked what strategies, if any; they had used to help them be successful on the three tasks. Names commonly reported were “tree (Christmas tree, pine needles, tree limbs), leaf (oak leaf, leaves), star (Ninja star), guitar (guitar strings, broken guitar), arrow, fan (ceiling fan), and flower”. Since such a large number of participants reported naming the stimuli as the strategy they used to facilitate performance, and since there was quite a bit of commonality among the names generated by the participants, the visual stimuli possibly did not provide a rigorous test of visual memory for nonverbal stimuli. Therefore, future research efforts should be directed toward developing stimuli that are more like their nonverbal counterparts utilized in the auditory and olfactory modalities. Development and use of such stimuli would provide a more rigorous examination of visual memory for nonverbal materials and allow for a stronger case when comparing performance across the three modalities.

### ***Recency-Primacy Shift Findings***

Previous research using verbal stimuli presented visually and research using nonverbal stimuli has demonstrated that the recency effect is more prevalent at short delays and that the primacy effect becomes more prevalent at long delays. Knoedler et al.'s (1999) Experiment 1 (1999) use of black and white line drawings and their corresponding names as stimuli in conjunction with a SPR task is an example of research demonstrating the recency effect at short delays and the primacy effect at longer delays. Korsnes and Gilinsky (1993) also demonstrated this finding using younger (aged 25 - 35, M=27 years) and older (aged 65

- 75, M=71.6 years) adults tested on a SPR task with slides consisting of black and white patterns and colored abstract paintings. Wright et al. (1985) demonstrated the finding using pigeons, monkeys and humans using kaleidoscope travel slides in conjunction with a SPR task. In each of these experiments, the recency effect was present at short delays and gave way to the primacy effect as the delay interval increased. These findings suggest that the recency-primacy shift with increased delay is characteristic of visual memory for both verbal and nonverbal stimuli. The findings also suggest that the recency-primacy shift occurs across species.

The present experiment also employed a SPR task yet there was no indication of a recency-primacy shift. The 5 x 3 x 2 mixed factorial ANOVA with repeated measures detected no significant effects of delay (i.e. no main effect and no interaction effects). Since the visual data were near or at a ceiling effect, to test for the possibility of the visual data masking any additional effects, a second analysis was performed to provide more insight regarding the nature of performance within the olfactory and auditory modalities. A 5 x 2 x 2 mixed factorial ANOVA was conducted (the visual data were dropped) and once again, there were no significant main effects and no significant interaction effects of delay ( $p > .05$ ). In fact, for the olfactory data, recognition was consistently better at the beginning and end of the list compared to performance on the middle portion regardless of delay interval. This finding is consistent with Reed's (2000) results at his short (3-seconds) but not at his long (30-second) delay.

For the auditory data, performance was better at the beginning and end of the list at the 3-second delay interval, but, as noted earlier, performance did decline at the 15-second delay interval. However, the findings at the 15-second delay interval might also reflect some

methodological concerns (probes represented opposite ends of range) and therefore drawing conclusions regarding the nature of SPE's at longer delays is premature. Additionally, although Knoedler et al. (1999) report a recency-primacy shift within the auditory modality based upon a significant interaction between serial position and delay, the methodology used in their experiment is also cause for concern (Their participants stated out loud a name for each stimulus as it appeared on the screen). Their method is confounded with presentation of a visual stimulus, which was verbal in nature and therefore did not provide a rigorous test of memory within the auditory modality. In light of the methodological concerns brought about by both experiments, additional research should explore methodologies, which would provide a purer test of memory for auditory stimuli. At present, the most that can be stated regarding primacy and recency effects within the auditory modality is that they can be obtained at short delay intervals, but the nature of the effects of longer delay intervals is not yet known.

One point regarding the recency-primacy shift worth noting is the many ways researchers have tested to determine whether or not the shift is present. Korsnes and Gilinsky (1993) provide descriptive evidence as support for the recency-primacy shift. They graph mean memory performance for the first and last list items as a function of delay interval and note where the performance lines cross. For the older participants, the lines crossed between the 1-sec and 50-second delay intervals, whereas for the young participants the lines crossed between the 50-sec and 100-second delay intervals. This, in conjunction with graphs of performance across list positions, is presented as evidence that older participants shift from recency to primacy earlier than do their younger counterparts with regard to delay interval.

Wright et al. (1985) used polynomial trend analyses regarding changes in serial position function as a basis for concluding that shifting from recency to primacy occurs earliest in pigeons, then monkeys, and finally humans. Knoedler et al. (1999) reported a significant interaction between serial position and retention interval to support the conclusion that participants shifted from recency to primacy with increased retention interval. The current experiment conducted a 5 x 3 x 2 mixed factorial ANOVA and found no significant effects of delay. An additional 5 x 2 x 2 mixed factorial ANOVA was conducted and once again, no significant effects of delay were found. Therefore, with regard to the findings in general, the present results indicate no shift from recency to primacy with increased delay for the olfactory modality. Additional testing is needed to address the possibility of a recency-primacy shift with increased delay in the auditory modality.

### ***Summary of findings***

The present olfactory results, along with those of Reed (2000), indicate that primacy and recency effects can be obtained within the olfactory modality. However, although SPE's can be obtained at a short delay, the lack of a recency-primacy shift when delay interval is increased, suggests that SPE's may not be directly comparable to those observed in the visual modality.

The auditory results also indicate primacy and recency effects can be obtained within the auditory modality. These results taken together with the olfactory results extend the generality of the SPE. However, due to methodological concerns, no conclusions can be drawn regarding the recency-primacy shift with increased delay interval in the auditory modality.

While there is much data on SPE's in the visual modality for verbal stimuli, no comparable findings were obtained in the present experiment. However, results from debriefing suggest additional efforts are needed regarding the efficacy of snowflakes as nonverbal stimuli. It is also worth noting, that if the ceiling effect was due in part to ensuring discriminability of stimuli, then results from experiments in which the stimuli were randomly sampled may reflect performance due in part to lack of discriminability rather than solely due to a failure of memory.

### ***Future Research***

Based upon the findings, several areas need to be addressed and thus provide an assortment of avenues to further investigate. One of the goals of the present research was to examine whether or not SPE's are characteristic of memory in general. Exploring this question required developing a method, which could be employed in each of the three modalities. The finding of a ceiling effect clearly indicates that the method is not developed to the extent that it is appropriate for the visual modality. The failure of the methodology to meet the overall goal in a satisfactory manner serves as the basis for several future experiments.

One way to address the issue could be to explore the development of stimuli. The auditory stimuli were a series of tones ranging from 75 Hz to 559 Hz. These stimuli were appropriate in the sense that they did provide a test of auditory memory for nonverbal stimuli. Results from debriefing indicated that the stimuli were treated as nonverbal, since no strategies that could be classified as verbal in nature were reported. The majority of participants reported having no strategy whatsoever for the auditory task. A few participants reported attempting to visualize where the tones were relative to one another. A few

participants also attempted to create a melody out of the tones. Additionally, a small number of participants reported not “liking” the auditory task because it was difficult, and they really didn’t know how to remember the stimuli.

While the stimuli were appropriate in the sense that they were nonverbal in nature, the range from 75 Hz to 559 Hz could be cause for concern. As discussed earlier, one of the trials for which position 4 was tested contained both ends of the range as probe stimuli and therefore may have facilitated performance. For that reason, additional work could be conducted to provide a set of auditory stimuli that are discriminable, but not overly distinct.

Research concerning development of visual stimuli is the area of most concern. Researchers have used abstract paintings (Korsnes & Gilinsky, 1993) and kaleidoscope patterns (Wright et. al, 1985) and obtained SPE’s. Although these stimuli do not have standard names assigned to them, they nevertheless may lend themselves to naming. One possibility could be to present a shape with a certain color and then generate additional stimuli as variants of that color. For example, a green disk could serve as the middle point and additional green disks that could only be judged as “lighter than the last one,” or “darker than the last one” could be used to create a short list of “green stimuli.” A probe item could then be presented, and the task would be to indicate whether the probe was contained in the list. This type of broad strategy is analogous to the strategy reported for the auditory task in which participants would visualize where the tones were relative to one another.

### ***Concluding remarks***

In conclusion, SPE’s have been a staple of memory research throughout the literature. Only more recently have researchers begun to investigate their occurrence in the auditory and olfactory modalities. The findings that SPE’s are present in young and old humans and in

other animal models suggest that they may be a fundamental characteristic of memory. The current results extend their generality to the auditory and olfactory modalities. However, SPE's did not become a staple in the visual modality overnight and therefore much more research is needed in these other modalities before broad generalizations are merited.

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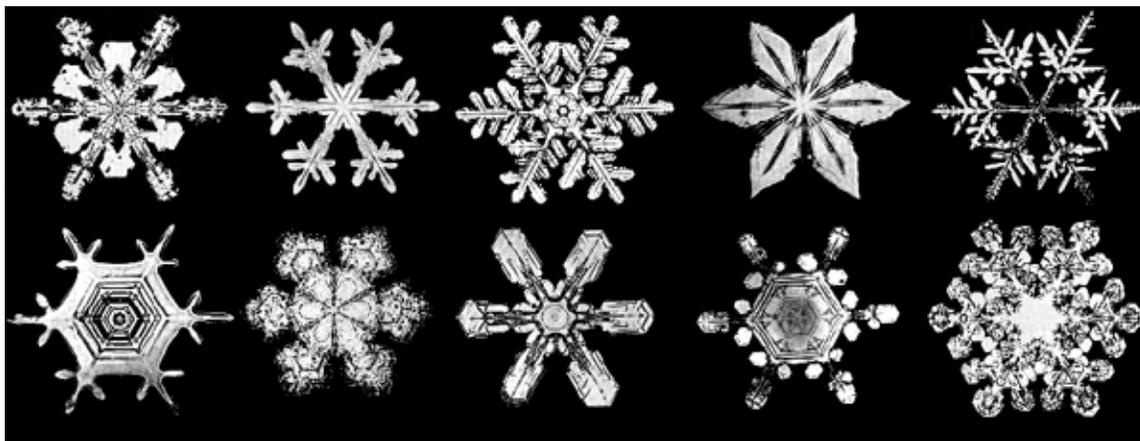
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## APPENDICES

Appendix A  
Olfactory Stimuli

1. Tea rose
2. Satsuma
3. Vanilla
4. Oceanus
5. Patchouli
6. Lilac
7. White musk
8. Sandalwood
9. Ananya
10. Dewberry

Appendix B  
Visual Stimuli



Appendix C  
Auditory Stimuli

75 Hz.

94 Hz.

117 Hz.

146 Hz.

183 Hz.

229 Hz.

286 Hz.

358 Hz.

447 Hz.

559 Hz.

## Appendix D

### North Carolina State University INFORMED CONSENT FORM

Title of Study: Learning and Memory in the Visual, Auditory and Olfactory Modalities: An Investigation Into the Generality of Serial Position Effects

Principal Investigator: Julie H. Petlick

Faculty Sponsor (if applicable) Dr. James Kalat

You are invited to participate in a research study. The purpose of this study is to investigate learning and memory for information presented using images, sounds and odors.

#### INFORMATION

1. List all procedures, preferably in chronological order, which will be employed in the study. Be sure to use lay language.  
Participants will be seated in front of a computer monitor and given procedural instructions. Participants will be presented with 5 images followed by 2 additional images called probes. The task is to indicate which one of the probes was also one of the original 5 images. After being tested with images, participants will then be presented with 5 sounds followed by 2 additional probe sounds. The task is the same as before; indicate which one of the sounds was also one of the original 5 sounds. The participant will then be presented with 5 odors followed by 2 additional probe odors; again the task is to indicate which odor was also one of the original 5. After participants have been tested using images, sounds and odors, they will rest for 2 minutes and then be retested once more with images, sounds and odors.
2. State the amount of time required of the subject per session and for the total duration of the study.  
This experiment will take approximately 45 minutes.

#### RISKS

Using lay language describe the foreseeable risks or discomforts, if any, of each of the procedures to be used in the study, and any measures which will be used to minimize the risks.

Some people experience headaches when they are exposed to odors for long periods of time. You will be exposed to a total of 7 odors (5 odors and two probe odors) for 3 seconds each for a total of 21 seconds per trial. You will be tested for 5 trials and will have a rest period between each trial. The likelihood of getting a headache is very small since the exposure time is for such a short period. There will be a fan blowing in front of you to keep the air clear. If you feel like you are getting a headache please let me know and you can rest or you are free to leave at any time and will still be given credit.

#### BENEFITS

List the benefits you anticipate will be achieved from this research, either to the subjects, others, or the body of knowledge.

This research will help psychologist have a better understanding of whether memory is specific to the way information is presented or if it is general. The research will be beneficial to participants because it might indicate that memory is better when information is presented a certain way (like with images or with sounds). Knowing which type of presentation is best for participants might provide them with better study habits.

#### CONFIDENTIALITY

**The information in the study records will be kept strictly confidential. Data will be stored securely and will be made available only to persons conducting the study unless you specifically give permission in writing to do otherwise. No reference will be made in oral or written reports which could link you to the study.**

#### COMPENSATION

**For participating in this study you will receive 2 credits. Other ways to earn the same amount of credit are described in your syllabus for your section of Introduction to Psychology. **If you withdraw from the study prior to its completion, you will receive full credit.****

**EMERGENCY MEDICAL TREATMENT** (if applicable)

There are no risks associated with this experiment. If at any time you would like to stop and take a break please let me know or if you decide you want to quit and leave the experiment you are free to do so without any penalty.

**CONTACT**

**If you have questions at any time about the study or the procedures, you may contact the researcher, Julie H. Petlick, at jdhinson@unity.ncsu.edu, or [231-8613]. If you feel you have not been treated according to the descriptions in this form, or your rights as a participant in research have been violated during the course of this project, you may contact Dr. Matthew Zingraff, Chair of the NCSU IRB for the Use of Human Subjects in Research Committee, Box 7514, NCSU Campus (919/513-1834) or Mr. Matthew Ronning, Assistant Vice Chancellor, Research Administration, Box 7514, NCSU Campus (919/513-2148)**

**PARTICIPATION**

**Your participation in this study is voluntary; you may decline to participate without penalty. If you decide to participate, you may withdraw from the study at any time without penalty and without loss of benefits to which you are otherwise entitled. If you withdraw from the study before data collection is completed your data will be returned to you or destroyed.**

**CONSENT**

**I have read and understand the above information. I have received a copy of this form. I agree to participate in this study.**

Subject's signature \_\_\_\_\_ Date \_\_\_\_\_

Investigator's signature \_\_\_\_\_ Date \_\_\_\_\_

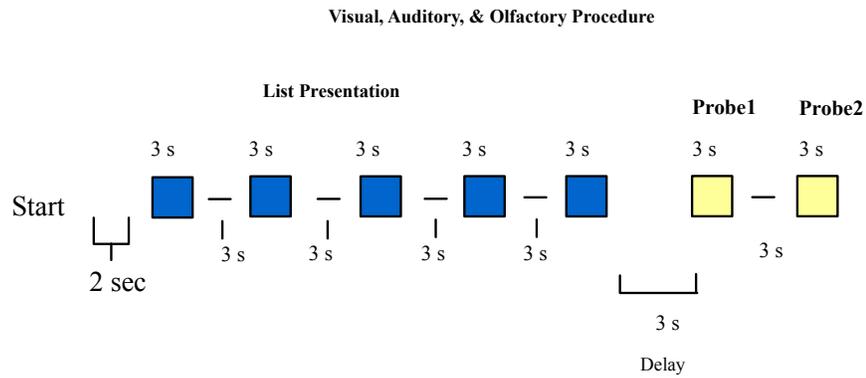
## Appendix E

### Visual Instructions

“I am going to give you the instructions for the visual task. You will not be using the keyboard so you can sit back but you will need to pay attention to the monitor. I will start each trial for you and when you are ready to answer you will do so by calling it out and I will record it. When the task begins, you will see the word START followed by 5 images displayed one at a time. After all 5 images have been displayed you will see a red dot signaling the end of the learning phase. You have now learned a list of 5 items. Following a delay, you will then see two more images that will be labeled Probe 1 and Probe 2. Your task is to indicate which of those probes was also contained in the list. Always wait until you have seen both probes before you respond. At the end of the trial indicate your response by calling out the answer at which time I will record it”.

## Appendix F

## Visual, Auditory, and Olfactory Presentation Rate and ISI for 3-second Delay Condition



## Appendix G

### Auditory Instructions

“I am going to give you the instructions for the auditory task. You will not be using the keyboard so you can sit back but you will need to pay attention to the monitor. I will start each trial for you and when you are ready to answer you will do so by calling it out and I will record it. When the task begins, you will see the word START followed by 5 tones presented one at a time. After all 5 tones have been presented you will see a red dot signaling the end of the learning phase. You have now learned a list of 5 items. Following a delay, you will then hear two more tones that will be labeled Probe 1 and Probe 2. Your task is to indicate which of those probe tones was also contained in the list. Always wait until you have heard both probes before you respond. At the end of the trial indicate your response by calling out the answer at which time I will record it. Even though this is an auditory task you need to remain focused on the screen because the word START will appear, and so will the words Probe 1 and Probe 2.”

## Appendix H

### Olfactory Instructions

“I am going to give you the instructions for the olfactory task. This task is just like the visual and auditory tasks except for the fact that this task does not involve the computer. You will need to focus your attention on the computer screen and basically continue to look at the white screen throughout the task. To begin the task I will say the word START and then I will present you with 5 odors one at a time. I will place each odor directly under your nose. You should inhale to the count of 1-2 seconds. After I have presented all 5 odors there will be a delay and then I will present you with 2 more odors. As I present those odors I will say Probe 1 and Probe 2. Your task is to indicate which of those probe odors was also presented to you in the list. Always wait until you have smelled both probes before you respond. At the end of the trial indicate your response by calling out the answer at which time I will record it. Even though this is an olfactory task you need to remain focused on the screen. If at anytime you feel light-headed or cannot smell the odors please let me know.”

## Appendix I

### Pilot test for snowflakes

Six hundred sixty-two snowflakes were received from Dr. Ian Neath (Purdue University). The experimenter selected 25 snowflakes and tested their discriminability. The 25 stimuli were arranged in a 5 x 5 matrix and displayed as a Web page. Ten individuals (5 male, 5 female) were given an instrument instructing them to make 3 different judgments or ratings while viewing the snowflakes (see Appendix J). Participants were first asked to indicate all snowflakes that they could easily distinguish from all the other snowflakes. Participants were then asked to indicate any snowflakes that were too similar and in addition indicate which snowflakes they were too similar to. Lastly the participants were asked to rate the ease with which each snowflake could be discriminated from the others.

The following selection criteria were used to interpret the data: 1) Any snowflakes that received zero votes as being too similar to another were placed on a list. 2) Any snowflakes that received all 10 votes as being easily discriminable, and received no votes as being too similar were added to the list. 3) Snowflakes receiving the largest number of easily discriminable votes were selected and those that had been reported as being too similar to it were eliminated. For example, snowflake #1566 received 8 votes as being easily discriminable but was also reported by one participant as being similar to #1436. Following the criterion, #1566 was selected and #1436 was eliminated. Selection continued in this manner. The resulting stimuli were 11 snowflakes that had never been reported as being similar to any of the others. One stimulus was randomly selected for rejection resulting in the 10 stimuli used in the experiment.

## Appendix J

## Instrument Used to Pilot Snowflake Discriminability

## Instructions

Below is a 5 x 5 matrix. To complete your task you will view a Web page that consists of 25 snowflakes arranged into 5 rows by 5 columns. Each cell in the matrix below corresponds to an individual snowflake contained in the Web page. The first cell below (row 1, column 1) corresponds to the first snowflake. Do you understand the way in which the matrix corresponds to the Web page of snowflakes?

Please indicate to the experimenter which cell below corresponds to the third snowflake located in the second row of the Web page.

You are ready to begin.

**Task #1** – Please indicate any snowflakes that you feel you could easily distinguish from all the others. Select as many as you can. Indicate these distinctive snowflakes by placing a checkmark in the corresponding cells.


**Task #2** - Please indicate any snowflakes that you feel are too similar to another snowflake and therefore would not be easily distinguishable. You may select as many as you feel are too similar. To indicate which snowflakes are too similar place a checkmark in the corresponding cell and also indicate which snowflake it is similar to by writing the number of the similar snowflake in the cell next to the check mark. So for example if I thought the very first snowflake was too similar to the very last snowflake I would place a checkmark in the first cell and also write the #25 in the first cell. Do you understand the procedure?

1	2	3	4	5
6	7	8	9	10
11	12	13	14	15
16	17	18	19	20
21	22	23	24	25

**Task #3 – Please rank each of the snowflakes using the following rating scale:**

1 = I could very easily distinguish this snowflake from all other snowflakes displayed

2 = I could probably distinguish this snowflake from the others with little difficulty

3 = I might be able to distinguish this snowflake from others if I really tried

4 = I could probably not distinguish this snowflake from one of the others if given a short amount of time

5 = I definitely could not distinguish this snowflake from one of the others if given a short amount of time

1	2	3	4	5
6	7	8	9	10
11	12	13	14	15
16	17	18	19	20
21	22	23	24	25

## Appendix K

### Summary of Pilot Test for Visual and Auditory Stimuli

In February 2003, prior to the experiment proper, a pilot test was conducted to determine whether the proposed methodology was appropriate to detect differences in performance or whether performance was at floor or ceiling.

#### **Method**

##### Participants

Fifteen participants enrolled in a research methods course at NC State University volunteered to serve as participants. Data for two participants were dropped for the visual task due to interaction with the instructor of the course during the time of instructions for visual task. The resulting sample was such that  $n=15$  for the auditory task and  $n=13$  for the visual task.

##### Procedure

Participants were tested for 10 visual trials followed by 5 auditory trials in a group setting. The format of the trial and the task was the same for both visual and auditory trials. Visual stimuli were projected onto a screen in the front of the classroom. Auditory stimuli were presented via the speakers connected to the instructor's workstation. The word, "Start," was displayed on the screen followed by 5 images of snowflakes (5 tones for auditory) presented one at a time. Presentation rate for stimuli was 3 seconds, inter-stimulus interval (ISI) was 3-seconds, and delay interval was also 3-seconds. Following the 3-second delay interval, two probe stimuli were presented one at a time and the participant's task was to indicate which probe had also been presented as part of the list for that trial. Participants

indicated responses by circling the corresponding answer on their data sheet (see Appendix L).

### Results

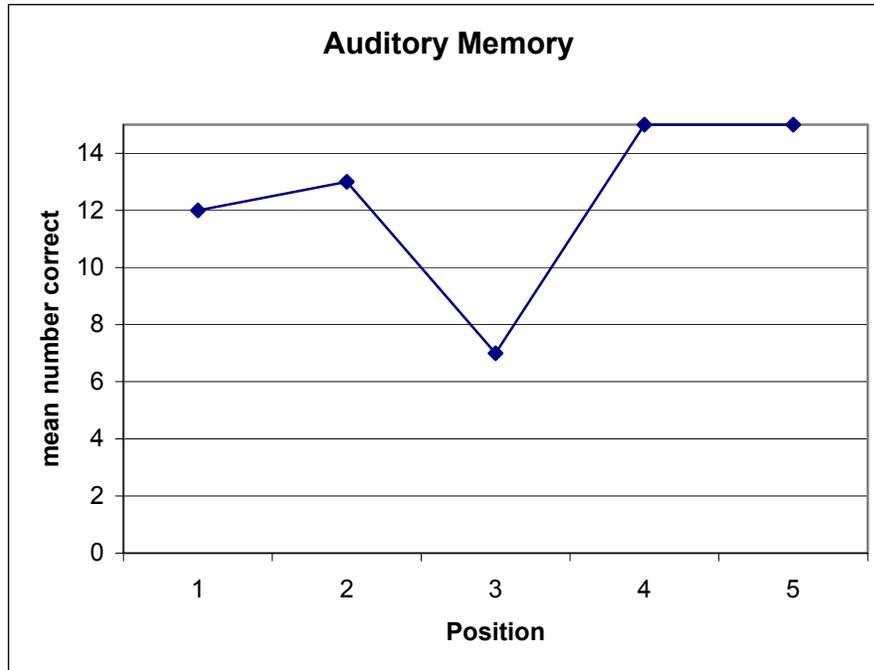
A one-way repeated measures ANOVA was conducted on the auditory data with a predefined alpha set at ( $p < .05$ ). An obtained [ $F(4,56) = 6.76, p < .05$ ] indicated that performance was significantly different as a function of list position (Table 9)

**Table 9. ANOVA summary table for auditory pilot**

Source	DF	SS	MS	F
Treatment	4	2.21	0.55	6.76*
Error	56	4.59	0.08	-

\* $p < .05$

The finding of significance was sufficient to indicate that the methodology was sensitive enough to detect differences in performance and that performance was not at floor or ceiling. Since the goal of the pilot test was just to ascertain whether or not the task was too easy or too difficult, no post hoc test was conducted. Figure 3 presents performance as a function of list position.



**Figure 4. Auditory task – Pilot test performance**

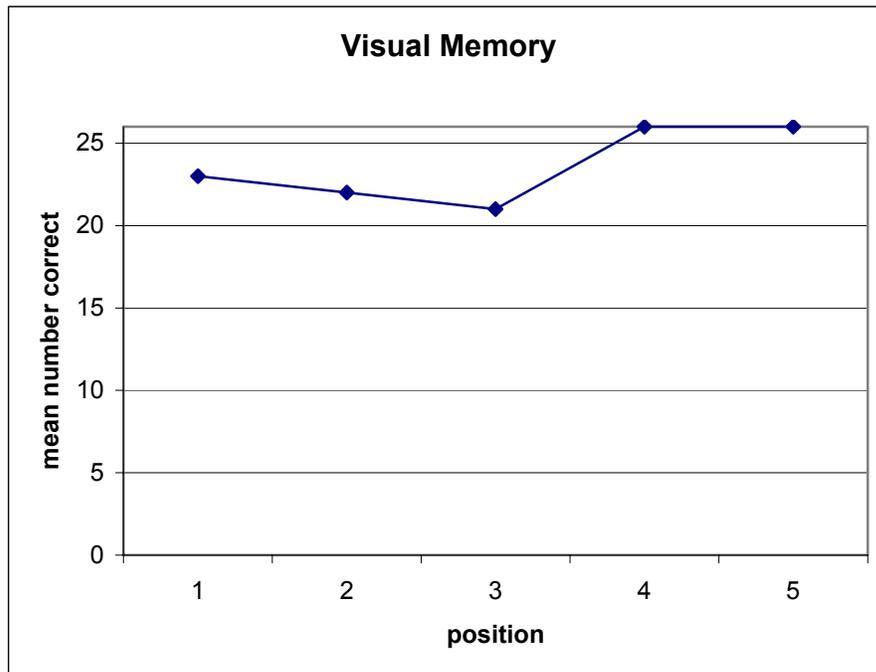
A separate one-way repeated measures ANOVA was conducted on the visual data with a predefined alpha set at ( $p < .05$ ). Two of the 15 participants were interacting with their instructor during the instructions for the visual trials and for that reason their visual data were not included in the analyses ( $n = 13$ ). Performance approached significance ( $p < .0795$ ) however, an obtained [ $F(4,48) = 2.23, p > .05$ ] indicated performance was not significantly different as a function of list position (Table 10).

**Table 10. ANOVA summary table for visual pilot**

Source	DF	SS	MS	F
Treatment	4	1.63	0.41	2.23
Error	48	8.77	0.18	-

$p < .0795$

Performance on the visual task as a function of list position is depicted in Figure 4.



**Figure 5. Visual task – pilot test performance**

### **Discussion**

The auditory findings indicated that the method and stimuli were indeed appropriate for the desired goals of the experiment. As for the visual findings, though the sample size was small, performance reflected the desired trend; therefore the method was judged to be within acceptable limits.

## Appendix L

## Data Sheet for Visual and Auditory Pilot Test

Thank you for participating in this pilot experiment.

You will be given 10 trials. On each trial you will view a list of 5 images (one at a time) followed by 2 probe images. YOUR TASK is to indicate which of the probe images WAS ALSO contained in the list. Focus only on the current trial when determining your response. Circle your answer at the end of each trial.

Trial 1	Probe 1	Probe 2
Trial 2	Probe 1	Probe 2
Trial 3	Probe 1	Probe 2
Trial 4	Probe 1	Probe 2
Trial 5	Probe 1	Probe 2
Trial 6	Probe 1	Probe 2
Trial 7	Probe 1	Probe 2
Trial 8	Probe 1	Probe 2
Trial 9	Probe 1	Probe 2
Trial 10	Probe 1	Probe 2

You will now hear 5 tones (one at a time) followed by 2 probe tones. YOUR TASK is to indicate which of the probe tones WAS ALSO contained in the list. Focus only on the current trial when determining your response. Circle your answer at the end of each trial. Although these trials involve sounds rather than images, please continue to look at the screen in the front of the room during these trials.

Trial 1	Probe 1	Probe 2
Trial 2	Probe 1	Probe 2
Trial 3	Probe 1	Probe 2
Trial 4	Probe 1	Probe 2
Trial 5	Probe 1	Probe 2