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Suffix effects, coding assessments, and intrusion errors in young and elderly subjects

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SUFFIX EFFECTS, CODING ASSESSMENTS, AND INTRUSION ERRORS

IN YOUNG AND ELDERLY SUBJECTS

by

JOAN M. GREENHUT-WERTZ

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

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Abstract

SUFFIX EFFECTS, CODING ASSESSMENTS AND INTRUSION ERRORS IN YOUNG AND ELDERLY SUBJECTS

by

Joan Greenhut-Wertz

Advisor: Professor Susan K. Manning

Five studies were conducted to investigate potential age differences in encoding, selective attention, and response inhibition in normal young and normal elderly college students. Three paradigms were employed. One attempted to evaluate the degree to which elderly subjects were able to exclude an extra item (a suffix) from the encoding and recall processes in immediate ordered recall. Another paradigm allowed the study of serial recall of phonologically similar and distinctive letters. In one condition, subvocal rehearsal was prevented by means of articulatory suppression, i.e. repeating the word "the" throughout the task. A final set of studies required subjects to make similarity judgements of letter pairs which were either phonologically or visually similar, in order to assess the degree of phonological coding employed. Again, in one condition, articulation was suppressed. Despite similar letter spans, serial recall was more difficult for the elderly than for the young. In some cases, auditory suffix interference was greater for the elderly than for young, and the elderly appeared to have been more

susceptible to a small degree of visual suffix interference than were the young. The elderly were less able to exclude the suffix from the response set than were the young, and made a greater number of intrusion errors, both suffix and extra-list, in all of the recall paradigms. The extra-list intrusion errors were phonological/alphabetic order in nature, suggesting that the elderly may experience task competitive, internally generated "noise", which enters the response set. Thus, an attentional type of deficit in terms of ineffective response inhibition on the part of the elderly is implied. The data derived from articulatory suppression during immediate serial recall suggest that elderly subjects depend more upon articulatory processes than do young. However, when articulation was suppressed in the similarity judgements studies, elderly subjects' reaction times showed a significant improvement, suggesting that the process of suppressing articulation, may have helped "boost the signal" and focused attention in the elderly subjects.

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My children, Michael, Freddy and Hannah deserve much credit for their tolerance and understanding of my absence and inattention on many occasions.

Finally, this work is dedicated to my grandmother, Johanna Arena Daidone, who, at age 87, continues to inspire me with her great love of life. She, along with the elderly subjects in my studies, has shown me that growing old can truly be a time to begin again.

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Suffix Effects, Coding Assessments, and Intrusion Errors in Young and Elderly Subjects

Age related deficits in cognitive functioning have been reliably documented in the literature, but their nature and extent are widely debated. Early on, Welford (1958) suggested that the basis for the overall decline in elderly learning and performance was a decrease in the functioning of short term memory. Until recently, a reduced storage capacity was commonly accepted as an interpretation of these deficits (e.g., Craik, 1977; Welford, 1958). However, some tasks, such as Forward Digit span, thought to be a measure of storage capacity, seem to remain relatively intact in older adulthood (see Baddeley, 1986, for a review).

Dobbs and Rule (1989) as well as Baddeley (1986) suggest that the basis for these divergent findings may be that tasks such as Forward Digit span involve passive processes, as contrasted with those tasks which require active engagement of working memory, the dynamic, more comprehensive conception of a short term memory system, introduced by Baddeley and Hitch (1974). Indeed much research of late has been devoted to the investigation of the role of working memory in age related short term memory deficits (e.g., Dobbs & Rule, 1989; Hasher & Zacks, 1988; Morris, Craik & Gick, 1990; Salthouse, 1991).

Working memory, as conceived by Baddeley and Hitch (1974), is an executive processor, assisted by sub-systems in relegating resources to the processing task at hand. One of the subsystems is the articulatory loop, which allows maintenance of items in the short term store for a brief period. This articulation process was deemed by Baddeley as use of the inner voice, resulting in the production of a phonological code. Later, this model was modified to include a separate phonological path, to which spoken material has obligatory access (see, for example, Salame and Baddeley, 1982). That is, spoken material will automatically be forwarded along that phonological path, whereas visual verbal material will be coded phonologically through articulation. (Indeed early work has shown that the short term memory code is primarily an acoustic/articulatory one, Conrad, 1964; Hintzman, 1967; Conrad and Hull, 1968).

The phonological store, as conceived by Baddelely and colleagues, is not dependent upon articulation, and spoken material has automatic access to it. For example, if a subject is presented in the auditory modality with acoustically confusable consonants, and subvocal articulation or rehearsal is prevented, the auditory confusions still appear, indicating that articulation is not necessary to access this short term phonological store. On the other hand, if a subject is presented visually with acoustically similar letters articulatory suppression eliminates the confusion effects which are normally present without suppression.

The work of Baddeley and his colleagues also suggests the existence of a separate visual store, termed the visuo-spatial scratch pad, a name intended to convey the strong spatial associations linked to items coded in this subsystem of working memory. In addition, Baddeley suggests yet another visual store for sequentially presented visual verbal material, which may have come about in the acquisition of reading skills.

A study by Vallar and Baddeley (1984) supported the concept of a separate visual store, based on evidence that patients whose short term memory functioning has been severely impaired perform consistently better than chance with visually presented span material, but only at chance levels when the items were presented auditorily.

Penney (1989) proposes a model of short term memory not unlike that of Baddeley (1986). Separate auditory and visual streams of verbal processing exist. Verbal items presented in the auditory modality have automatic access to an acoustic or A code, while those presented in the visual modality are coded in a phonological, or P code, via silent articulation. If this encoding process is disrupted, then a simultaneously generated, purely visual code may be accessed.

The major difference between the two is that in the Baddeley model, auditory, as well as visual, articulated stimuli are coded in the phonological code, while the Penney model proposes the existence of a separate A code for auditory stimuli.

In general, auditory presentation of stimuli results in superior recall performance, especially in immediate serial recall paradigms (e.g. Crowder & Morton, 1969; Penney, 1975), and several studies have shown that differences in performance in these two modalities are greater for the elderly than for the young.

One frequently cited work of major impact is that of Mc Ghie, Chapman and Lawson (1965), in which visual and auditory immediate memory was investigated in young, middle aged, and elderly adults. They employed sequences of digits pairs which were presented .5 seconds apart in the visual and auditory modality. One digit was repeated in a sequence of five pairs. Four conditions were distinguished: digits that were originally presented in the auditory and then repeated in the auditory (AA), or in the visual (AV), and digits that were presented originally in the visual and then repeated in the visual (VV), or auditory (VA) modality. The task was to write down the digit that had been repeated. The premise here was that if the subject responded correctly, it was an indication that the digit had been stored or represented in immediate memory. Moreover, the digits that were not repeated served as distractor items.

The results showed that those items presented originally in the visual modality, regardless of the mode in which they were repeated, were more poorly retained for all age groups, but the difference increased significantly with age. Differences among the groups in the auditory presentation modality, regardless of the repeat modality were evident but not significantly different. It was conjectured that for elderly subjects, decline in visual short term memory was due to the strain imposed upon an already limited storage capacity by the necessary recoding of the incoming stimulus from visual to aural form, which is a more durable one.

Arenberg (1968) conducted a study to see if active rather than passive auditory augmentation of visual stimuli might decrease the age differences in short term recall. Four digits, each with a duration of .5 seconds, were shown sequentially on a screen. The last digit was followed by a 2 sec interval in which nothing appeared on the screen. Following this interval, three more digits appeared, which the subjects were always required to say, but not to recall. After the last of these digits, subjects were required to recall the first four digits in written form. Three conditions were included: an active auditory, in which the subjects read each of the four digits aloud, a passive auditory, where the experimenter read the digits aloud as they appeared on the screen, and a visual, which required silent reading of the four digits.

Results showed that the difference between visual and auditory performance (both active and passive), was significantly greater for the elderly than for the young. Arenberg interprets this as the elderly deriving more benefit from auditory presentation than do the young. However, while both groups did better in the active auditory than in the passive condition, the differences in performance were about the same for both groups, or both groups benefitted equally from the active input. Therefore, active articulation of the visual stimuli seemed crucial in boosting the elderly performance as compared to the silent visual condition.

Taub (1972) was interested in assessing age differences on several digit span tasks, some of which involved both auditory and visual presentation, and required both oral and written responses. One question of particular concern was whether or not young and elderly subjects with equivalent Wechsler Adult Intelligence Scale Forward Digit Spans would perform equally well on different types span tasks. Taub pointed out that this subtest was often used to equate level of functioning for studies on aging which involved different rates and modality of presentation, different modes of response, and various levels of task difficulty.

Stimuli consisted of lists three to nine digits in length, presented at the rate of one per second. Visual presentation involved a memory drum, and auditory stimuli were tape recorded. Lists were presented in order of increasing length, and after the subject failed to correctly respond twice for a particular list length, the length of the preceding list was taken as the span for that condition. Subjects were required to recall the digits in serial order, and to write or speak their responses. The Auditory Forward Span was estimated first and then the two visual spans, written and spoken, were assessed.

There was no difference in the Auditory Forward Spans of young and elderly subjects; neither was there a difference for young subjects between the Forward Span and the two visual span tasks. However, the elderly showed a significant decline in both visual spans as compared to their Forward Span. Elderly subjects also exhibited significantly shorter visual spans than did the young.

Manning and Greenhut-Wertz (1990) study of serial recall of auditorily and visually presented letters demonstrated inferior performance for visual as compared to auditory stimuli on the part the elderly subjects.

However, Taub (1975) studied presentation modality for unrelated digit materials and prose passages in young and elderly subjects, and found that while elderly subjects had significantly shorter spans in both visual and auditory conditions than the young, both groups showed superior recall in the auditory over the visual modality, and the difference was no greater for either group.

Other investigations of age related performance decrements in learning and memory performance has centered on the executive processor and its capacity, such as that of Hasher & Zacks (1988), which investigates the role of working memory in discourse comprehension. They conceive of working memory as a "limited capacity mechanism which shares its resources between a storage function ... and a set of processing functions" (p.196).

One of the processing resources increasingly favored as being central to age related declines in performance on learning and memory tasks is attentional capacity. Kahneman (1973) proposed that attention is an energy resource that is limited. Briefly, impinging auditory and visual stimuli are organized into perceptual units with regard to location in space, viz., clusters of visual and auditory stimuli emanating from a particular place. This initial appropriation is, for the most part, automatic and unconscious, requiring little or none of the attentional resources. As the processing progresses toward a response, the attentional demands increase.

Hasher & Zacks (1979) embraced this type of model, as well as others similar to it, and developed a limited attentional capacity framework within which the memory performances of a variety of groups could be understood. They proposed that cognitive functions operated along a continuum on which automatic and effortful processing are the endpoints. Automatic processes are those that impose a minimal taxation on our attentional capacity (spatial, temporal and frequency-of-occurrence information), while effortful processes (rehearsal and mnemonic strategies) are those which drain it. Age, (as do high arousal levels and psychological depression), limits attentional resources. Therefore, when elderly individuals are required to participate in a task which is effortful, a decline in performance will result; execution of an automatic operation will not result in an age related decrement. Of course, in the interest of avoiding a circular argument, these processes must be characterized as effortful or automatic independently of any differential performances of age groups.

Integrally related is the notion that elderly subjects are less able to ignore or filter task irrelevant information than are the young; selective attention is impaired. McDowd & Filion (1992) conducted a study in which the ability to filter irrelevant and attend to relevant stimuli was evaluated within a psychophysiological paradigm which elicited or inhibited an orienting response (OR). The OR is described by them as:

> a complex pattern of skeletal, physiological, and behavioral changes that is reliably elicited by any relatively innocuous stimulus that is novel, unexpected, interesting, or significant. Physiologically, the OR typically consists of a

momentary increase in skin conductance, cephalic blood flow, and pupil dilation and a momentary decrease in heart rate and peripheral blood flow (p. 66).

The skin conducting orienting response (SCOR) was used to gauge the degree to which both age groups were able to successfully ignore stimuli, the hypothesis being that elderly subjects would find it far more difficult to do so.

Subjects in the 'ignore' condition were told to pay no attention to a series of tones that were played simultaneously with a taped broadcast of a radio play. Those in the 'attend' condition were told to pay close attention to the tones, to count them, and to be sure to note if they all sounded alike.

Young adults were able to respond differentially, their SCOR diminishing significantly in the ignore condition. The elderly, on the other hand, showed no SCOR difference as a function of instruction; they persisted in attending to the to-be-ignored tones. It is suggested that a failure of inhibitory processes is the basis for age related attentional deficits, in that more of the elderly's attentional resources will be spent in the processing of irrelevant stimuli.

Indeed evidence for a greater distractibility in memory tasks on the part of the elderly was noted early on by Welford (1958). In his classic work on short term memory, he noted that elderly short term memory deficits may have their root in an increasing vulnerability to interference from other competing tasks, and suggested that the Forward Digit span task may minimize this type of interference. He reviews a series of studies conducted by Speakman, in which subjects were required to turn over a series of numbered cards, and in so doing, to count the number of cards turned, until a predetermined number of cards had been counted. Before beginning the counting, subjects were presented with a four digit number without warning. Young and old were equally capable of performing the counting task, but significantly fewer elderly were able to correctly recall the four digit number than young. When the study was repeated, there was no change in young performance. Elderly performance in the digit recall task was improved to the point where it was equivalent to that of the young, but showed significantly poorer performance in the counting task. Welford's interpretation of the elderly performance was that the simultaneity of the tasks was responsible for interference in immediate memory. That is, working memory deficits were apparent for the elderly subjects.

Decades of research has, for the most part, confirmed that elderly are unable to divide their attention between tasks or to selectively attend to stimuli as well as young subjects (see Plude & Hoyer, 1985, for a review).

It seems then that the elderly may have increasing difficulty processing visual stimuli into phonological form

(Manning & Greenhut - Wertz, 1990; McGhie, Chapman & Lawson, 1965; Taub 1972), or that visual representation in short term memory suffers, so that there is an emphasis on subvocal articulation. In addition, selective attention and response inhibition may be on the wane for the elderly, all of which may contribute to an overall picture of failing memory and faulty learning.

Briefly, the three studies presented here sought to investigate these issues of coding, selective attention, and response inhibition with paradigms that have seldom, if ever, been used in normal elderly populations. Two designs involved immediate serial recall. One included a suffix condition, which attempted to evaluate how successful elderly subjects were in barring this extra item from the encoding and recall processes. The other paradigm studied serial recall of phonologically similar and distinctive letters, with an articulatory suppression condition.

A final design required subjects to make similarity judgements of letter pairs which were either phonologically similar, visually similar or dissimilar, in order to assess the degree of phonological coding employed. This task also included an articulatory suppression condition, in order to minimize phonological coding, with the intent of inducing a heavier reliance on a visual pathway to short term memory, as discussed by Vallar & Baddeley (1984) and others.

Thus, a convergence from three separate but related paths upon the issues of coding and response inhibition in normal elderly subjects was attempted.

THE SUFFIX EXPERIMENTS

Age differences with regard to presentation modality (Mc Ghie, Chapman & Lawson, 1965; Arenberg, 1968; Manning & Greenhut, 1990; Taub,1972) and selective attention and response inhibition (Plude & Hoyer, 1985; Hasher & Zacks,1988; McDowd & Filion, 1992) have been documented in the literature.

One paradigm which offers the opportunity for studying all of the above, yet has seldom been employed, is that of the stimulus suffix. A suffix is a not-to-be remembered item appended to a sequence of items which is to be recalled. The stimulus suffix effect most commonly refers to the elimination or reduction of recency, which is the superior recall of the final as compared to middle items or to the penultimate item of the sequence.

The modality effect refers to the well documented findings that recency is usually greater in the auditory than in the visual modality. The suffix exerts its detrimental effects primarily in the auditory modality; visual suffix effects have been reported (Hitch, 1975) but Greene (1987) failed to replicate them.

Crowder and Morton (1969) have accounted for both modality and suffix effects by postulating the existence of a pre-categorical acoustic sensory store (PAS). Auditory sensory information was passively admitted and lingered briefly (a few seconds at most, p.366). This lingering acoustic information was believed to extend an auditory advantage in the recall of the final item or items presented in the auditory mode. These items could then be retrieved from the sensory store to the short term memory. The duration of visual sensory traces were much briefer than auditory, and therefore were not available to assist in the recall of final items presented in this modality. Hence auditory, but not visual recency resulted. The auditory suffix effect resulted from the suffix displacing the final item or items from the PAS, thereby eliminating recency.

Since its introduction, the theory has come under a barrage of criticism for its inability to account for number of empirical observations, and a number of amendments and revisions have been offered.

One such serious challenge was posed by Spoehr and Corin (1978), who proposed that the suffix effect results from the disruption of short term memory rather than from the displacement of the final item from PAS. In one study, subjects were presented aurally with lists of numbers; the mode of recall was written. The conditions included were six: a control, in which there was no suffix, a "Z-E-R-O" card suffix, a "0" card suffix, an auditory suffix "zero", spoken by the experimenter who was not in sight, a suffix in which the experimenter's mouth is visible and speaks the word "zero", and finally, a visual suffix with articulatory cues, in which the experimenter mouths the word "zero".

Both spoken suffixes, as well as the mouthed suffix, resulted in the suffix effect, while the others did not. Since the card suffixes were not disruptive, it was assumed that the visual suffix with articulatory cue condition, i.e., the visible mouthed suffix, did not draw its interfering effect solely from its visual component, and there was certainly no production of an auditory stimulus to account for the interference. Rather, the interpretation was that the list information had already been coded in short term memory, specifically in the articulatory code which was thought to be the dominant code of short term memory (see Hintzman, 1967; Conrad & Hull, 1968), and that the mouthed suffix interfered at the level of acquiring an articulatory code for the final item.

In a second study, non-linguistic auditory stimuli were investigated. A series of sounds made by common objects was presented, and subjects were required to recall the stimuli by either writing the name of the object which produced the sound, or by arranging a set of drawings of the objects in the order in which the sounds they made had been presented. The intent was to require subjects in the written response condition to recode the stimuli into a verbal format, and subjects in the picture arranging response condition to recode the items into a visual format. Five suffix conditions were included: a control (non-suffix), a sound suffix, a spoken name of a sound producing object, a written name of a sound producing object, and a picture of a sound producing object.

In the written recall condition, a suffix effect was produced by the sound, the spoken name of the object and the written name of the object. In the picture ordering conditions, all suffix conditions depressed final item performance, the outstanding difference being that the suffix picture of the sound producing object also produced the effect.

From these data Spoehr and Corin concluded that the suffix will be detrimental only when it is at the same level of processing by the subjects as required by the experimental conditions. That is, in the written recall condition, the sound, spoken name and written name suffix interfered with final item recall because all of these steps are involved in the recoding of the sound to a written name of the object that produced it. However, the picture suffix was not interfering since at no time was formulation of a picture code required. Similarly, all of the suffixes were interfering in the picture ordering condition, because an additional pictorial, visual representation was required. Thus, the notion of the suffix displacing a passively received, unprocessed acoustic stimulus from PAS was untenable in light of these data.

Campbell and Dodd (1980) and Greene and Crowder (1984) showed that lip read or mouthed stimuli, which are not auditory, showed recency and suffix effects. In summary, the PAS account of recency and suffix effects has proven to be more enduring than encompassing. Recognizing this, Crowder (1983) and Greene and Crowder (1984) have made revisions of the PAS account of recency and suffix effects by redefining pre-categorical acoustic storage to include the process of pre-categorical feature selection. Speech movements generated by self or others, would allow for selection of auditory features which could then enter the PAS. The feature selection remains pre-categorical because it occurs prior to any lexical processing.

Another aspect of the suffix effect that has come to be scrutinized is the noted effect the suffix has at positions in the sequence other than the last. Baddeley and Hull (1979) concluded that there are two suffix effects, one which is responsible for the performance decrement at the last position, and another that is pervasive throughout the rest of the sequence. Balota and Engle (1981) manipulated practice and presentation rates. With practice, subjects were able to develop the appropriate strategy for maximizing performance at a specific presentation rate. However, this was only true in the case of positions one through six, the preterminal portion of the sequence. Performance at the final position was impervious to any manipulation. Balota and Engle conclude that their results are indicative of an "attentional/strategic" factor (p.355) underlying the preterminal suffix effect. They propose that practice with suffixed lists may allow subjects to redistribute attentional capacities such that they pay more attention to list items and less to the suffix. That is, they are employing selective attention.

Regardless of whether the suffix and related effects are completely understood, they are generally reliable and robust, a fact to which the 20 years of research and debate surely attests. As such, these effects have the potential to be able to differentiate certain populations.

One such population is the elderly. Besides providing additional information about letter span in the elderly, the paradigm involves a degree of response inhibition and distraction, since it is necessary to encode and recall the list items in series and to keep the suffix outside of the response set. In addition, the preterminal suffix effect, as noted above, is sensitive to attentional demands. Since the elderly have been noted to exhibit decrements in attentional capacities, performance under the suffix condition might very well be another indicator of such a decline.

Manning and Greenhut (1990) studied recency and suffix effects in the young and elderly for the visual and auditory modalities. Subjects were presented with six letter lists in each condition. The letters J,Q,R,L,S,M were chosen to minimize both auditory and visual similarity (Manning, 1977). Half of the lists were suffixed with the letter Y. Taped auditory lists were heard through headphones and visual stimuli were presented on a desktop or a portable computer. Recall was written and in strict serial order with no backtracking permitted.

In the control condition, results showed young performance to be significantly better than elderly. Elderly subjects had a significantly better recall in all positions in the auditory modality than in the visual, and this difference increased at the end of the sequence. Young subjects, however, showed a significantly superior performance in the auditory modality as compared to visual in the last positions only.

Concerning the suffix conditions, again the young showed overall superiority in both conditions. In the auditory mode, a significant suffix effect was seen in positions two through six for the elderly, but only in positions four through six in the young. The overall suffix effect in this modality was significantly greater for the elderly than for the young. In the visual mode a small but significant suffix effect was seen at the last position for elderly subjects.

Apart from the overall age differences observed, a visual inferiority or deficit in performance for elderly subjects is suggested by these data, as is a greater susceptibility to auditory interference on the part of the elderly. Moreover, the basis of the differential performances may lie in the greater difficulty elderly subjects encounter in recoding stimuli. Mc Ghie et al. (1965) suggested that the normal recoding of brief visual stimuli into phonological form may overburden elderly short term capacity.

Evidence suggests that a visual short term store may be directly accessed (Hitch et al., 1989; Vallar & Baddeley, 1984). Further, Ross (1983) cites evidence that meanings of printed words can be accessed by either recoding the word phonologically or by directly accessing the lexicon by means of visual representation or the characteristics of the word. It is possible for silent reading to be accomplished without auditory recoding, and the young may be able to do this to a greater degree than the elderly.

In fact, speed reading techniques discourage phonological coding, focusing instead on improving the ability to extrude from the text several words simultaneously, using a sort of visual "photography", as it were.

It is possible that young subjects may be better able than elderly to employ a dual coding strategy (visual and phonological), the elderly having become more dependent upon a phonological code.

The small but significant visual suffix effect seen in the older subjects' data may be accounted for by the elderly having been unable to prevent phonological coding of the suffix. If, in their recoding from visual to phonological, the elderly recoded the suffix also, then it may have exerted a weakly interfering effect (similar to one condition of Spoehr & Corin, 1978). Young subjects may have dealt with the matter differently: phonological coding of the visual suffix may have been avoided, the suffix having had access to a visual channel only. Consequently, it had little effect in this condition. Indeed several of the young subjects reported that in the visual condition, they were able to think of the suffix as a "period", so that it never entered the to-be-remembered set. Hence, a failure to selectively attend to the letter set and exclude the suffix may be the basis for an increased susceptibility for suffix interference on the part of the elderly in both auditory and visual modalities.

Several possibilities then, are presented in considering age related deficits in immediate memory and in the suffix paradigm, as shown in Manning and Greenhut-Wertz (1990): the elderly may suffer from a decreasing ability to access short term memory through a visual channel, and therefore are more dependent on phonological coding and the articulatory processes necessary to accomplish it. Of course, the coding mechanism itself, the articulatory loop, may be compromised with age. This, combined with increasing difficulty in selectively blocking suffixes, may account for poorer visual performance and greater susceptibility to auditory interference, respectively.

The experiments reported here attempt to expound on the ability of the suffix paradigm to differentiate age groups with respect to a few basic cognitive processes.

In addition, the role of response mode is studied. Both oral and written recall are used to see if requiring subjects to recode the information to the format of the required response mode will elicit age related differences in the suffix and modality effects. As discussed above, Spoehr and Corin (1978) proposed that the suffix would have its effect at the level of coding, and it is reasonable to assume that varying response mode in this paradigm might maximize and minimize this type of recoding. For example, an auditory presentation which requires an oral response (as does the forward digit span) may minimize any recoding, whereas written response to an oral presentation may maximize it. Differences, regardless of whether they interact with age, may be of interest in that many studies seem to use one or the other without clearly considering the possibility of important differences in response format.

Uniform age differences in performance favoring the young are predicted, and the suffix should be more disturbing to the elderly than to the young, especially in the auditory condition. It is expected that elderly auditory performance will surpass visual.

Written recall should be better than spoken in the visual condition, and spoken recall should surpass written in the auditory modality. Since spoken recall of visual stimuli represents the situation which maximizes the probability of recoding visually presented stimuli to an auditory form, elderly subjects should show a relatively greater performance deficit in this condition as compared to the young, especially in the suffix condition.

Experiment 1

Method

Subjects

Sixteen young and elderly subjects were recruited from among Hunter College students. The 11 female and 5 male young subjects were between the ages of 20 and 29 with a mean age of 25.25 years. Nine were in their senior year, and seven were graduate students in programs based at the college. The 13 female and 3 male elderly subjects ranged in age from 61 to 78 years, with a mean age of 68.2 years. Three of these had attended college in the past for 1 or 2 years, seven subjects had previously earned a B.A. or B.S. degree, one had earned a Ph.D., one had earned an M.D., one had completed a masters degree and one subject had completed 2 years of graduate school. One did not attend college at all but did graduate from a commercial art school, and one subject's educational background was inadvertently omitted. All but one of the elderly who participated were taking classes at Hunter College for the sake of enjoyment; one was a matriculated student who had recently been awarded the Hunter College writing prize.

All subjects were able to see the stimuli with no difficulty and none were taking medication or had medical problems that could have interfered with cognitive functioning.

Both groups of subjects were administered the Mini-Mental Status test (Folstein, Folstein & McHugh, 1975). This test is an instrument which screens for dementia of Alzheimer's type as well as other cognitive aberrations in a very general way. The minimum score necessary to participate in the present experiment was 27 out of a possible 30 points, a score well within normal range. The data of those scoring below were eliminated from the study. The mean Mini-Mental score for the elderly was 29.88, for the young, 29.63. No elderly subject scored below 27, while two young subjects were excluded and replaced because of scores below 27.

A forward letter span measure, administered in the manner of the Wechsler Adult Intelligence Scale Forward Digit Span, was also obtained for each subject and the data of subjects with letter spans below 5 were excluded. The mean letter span for the young was 6.00 letters, for the elderly, 5.63.

The study was conducted at Hunter College.

Stimuli and Experimental Design

For the immediate recall portion there were eight conditions in all: auditory control-written recall, auditory control-spoken recall, visual control-written recall, visual control-spoken recall, auditory suffix-written recall, auditory suffix-spoken recall, visual suffix-written recall, visual suffix-spoken recall. The uppercase letters J,Q,R,L,M,S,H were chosen to minimize inter item auditory and visual similarity (See Manning, 1977, for rating procedures). Eight lists consisting of eight randomly chosen sequences, each being seven letters in length, were constructed. The suffix was either the letter V or the letter Y, both of which were randomly assigned to the lists, with the restriction that they appear an equal number of times within lists. Control sequences ended in a dash (-), which was to be viewed but not recalled. This dash was included in order to eliminate the extra time that would have been available at the end of the sequence in the control condition.

One half of the subjects received the auditory condition first and half received the suffix conditions first. Written and spoken recall were counterbalanced within this framework. Each subject received all eight conditions and all eight lists in a different order. List order was arranged to subscribe to two fully balanced 8 X 8 latin squares.

Apparatus and Procedure

All stimuli were presented on a Fountain IBM compatible computer with an 8088 microprocessor and an eight mhz clock speed.

For the immediate recall portion of the study, letters were presented at the rate of one per second (.5 second on, .5 second off) and the interval between sequences was 20 seconds. A "READY" signal of approximately .5 seconds in duration preceded each list, and the time between the offset of this warning signal and the first element of the list was 1.5 seconds. The visual presentation consisted of silent reading of the letters, while auditory required the subject to read the letters aloud as they appeared. Recall was in strict serial order (as verified by the experimenter, who sat close by "reading" a book but also monitoring the written recall in an unobtrusive manner), and for the written response conditions responses were recorded in booklets of eight pages, each page consisting of seven horizontal blanks to correspond to the number of letters in each sequence. When subjects were finished recording their responses, they turned to the next page. Thus, they could not refer back to previous lists. This type of written recall was employed with the intent of arriving at some degree of equivalence between this condition and the oral response condition, in which the subjects had to repeat the sequence in strict serial order to the experimenter, all the while never having any previous list letters available for viewing. Subjects received two practice sequences before each condition, the constituent letters being randomly chosen anew by the computer for each practice trial. Subjects were instructed to view the suffix and the dash as recall signals which themselves were not to be recalled. No back tracking was allowed.

Results

An item was counted as being correct only if it was recalled correctly and in the correct position. The maximum number correct at each position was 8 letters. The data for young and elderly groups in the control conditions are presented in Table 1.

A 2 (Age) X 2 (Recall) X 2 (Modality) X 7 (Position) analysis of variance (ANOVA) was performed on the control data, yielding significant main effects of age, F (1,30) = 18.14, MS = 31.10, p < .00001; and position F (6, 180) = 55.87, MS_{ϵ} 2.27, p < .00001. These were due to the young recalling more items than the elderly and standard serial position effects. Marginally significant main effects of Recall Method, F(1,30) = 3.54, MS_{ϵ} = 4.03, p =.068, and Modality, F (1,30) = 4.13, MS_{ϵ} = 8.47, p = .0512, were due to written recall being superior to spoken recall and to recall in the auditory modality being superior to that in

Table 1

Mean Number of Correct Responses for Young and Elderly Subjects as a Function of Modality, Recall Method, and Position in Experiment 1

	Serial Position							
Young	1	2	3	4	5	6	7	M
Written								
Aud. Control	7.38	6.69	5.88	5.19	5.31	5.50	7.56*	6.21
Vis. Control	7.50	7.12	6.50	5.62	5.50	5.06	4.94	6.04
Spoken								
Aud. Control	7.56	6.56	6.12	5.62	5.75*	5.94*	7.06*	6.36
Vis. Control	7.37	6.44	5.75	5.12	4.56	4.62	4.75	5.52
Elderly								
Written								
Aud. Control	6.38	4.88	4.44	4.37	3.56	3.81*	5.19*	4.66
Vis. Control	6.63	5.81	5.25	4.44	3.81	3.00	3.00	4.56
Spoken								
Aud. Control	6.75	5.13	4.06	3.69	3.13	3.81*	5.00*	4.50
Vis. Control	6.88	5.44	4.31	3.69	3.06	2.56*	2.50*	4.06

Note. * Denotes a significant Dunnett test; C - E = .59.

the visual modality, respectively.

The following significant interactions were obtained: Modality X Position; $F(6,180) = 23.84$, $MS_e = 1.32$, $p < .00001$, Recall Method X Modality; $F(1,30) = 4.82$, $MS_e = 3.06$, $p = .0360$ and Age X Position, $F(6,180) = 3.05$, MS_e 2.26, $p = .0072$. These were due, respectively, to superior performance at the later positions in the auditory as compared to the visual mode, equal performance in both recall conditions in the auditory modality, but superior performance in written recall of visual stimuli, and the inferior performance of the elderly as compared to the young at the later list positions. The last finding is notable since the letter spans of both groups were not significantly different and were quite close.

Recency and modality effects

Recency was defined as the superior performance for the final as compared to the penultimate list item, and one tailed t - tests were performed in which performance on the penultimate was subtracted from that of the final item. In the visual condition, young subjects showed no significant recency effects in either the written, $t(15) = .26$, $p > .05$; or in the spoken, $t(15) = -.355$, $p > .05$; recall condition. Likewise, the elderly showed no recency in the written, $t(15) = 0$, $p > .05$; or spoken $t(15) = -.279$, $p > .05$ conditions.

In the auditory condition, under the written recall condition, recency for both the young and elderly was present, $\underline{t}(15) = -6.15$, $\underline{p} < .001$, and $\underline{t}(15) = -2.71$, $\underline{p} < .01$, respectively. Similarly, in the spoken recall, both young and elderly showed recency, $\underline{t}(15) = -4.14$, $\underline{p} < .001$ and $\underline{t}(15) = -2.97$, $\underline{p} < .01$.

Planned Dunnett tests using the Age X Recall Method X Modality X Position error term, C - E = .59, were performed to investigate possible age differences in performance with respect to modality and serial position (noted in Table 1). These tests indicate that in the written recall condition, young subjects performed significantly better in the auditory than in the visual modes at Position 7, while elderly subjects showed significantly better performance in the auditory as compared to the visual mode at positions 6 and 7. In the spoken recall condition, young subjects showed superior auditory as compared to visual recall in positions 5, 6 and 7 while the elderly showed auditory over visual superiority at positions 6 and 7. Thus, it appears from these data that no great modality differences exist with respect to age and serial position.

To investigate the differences between auditory and visual performance, a score, designated the discrepancy score (DS), was calculated for all subjects by subtracting overall performance in the visual condition from overall performance in the auditory condition. Spearman Rank order ($\underline{r}_r$) correlations were performed between the DS and auditory performance and also between the DS and visual performance. The highest score and the largest DS were ranked as "1". These r_r's allow assessment of the loading of the auditory and visual components on the DS.

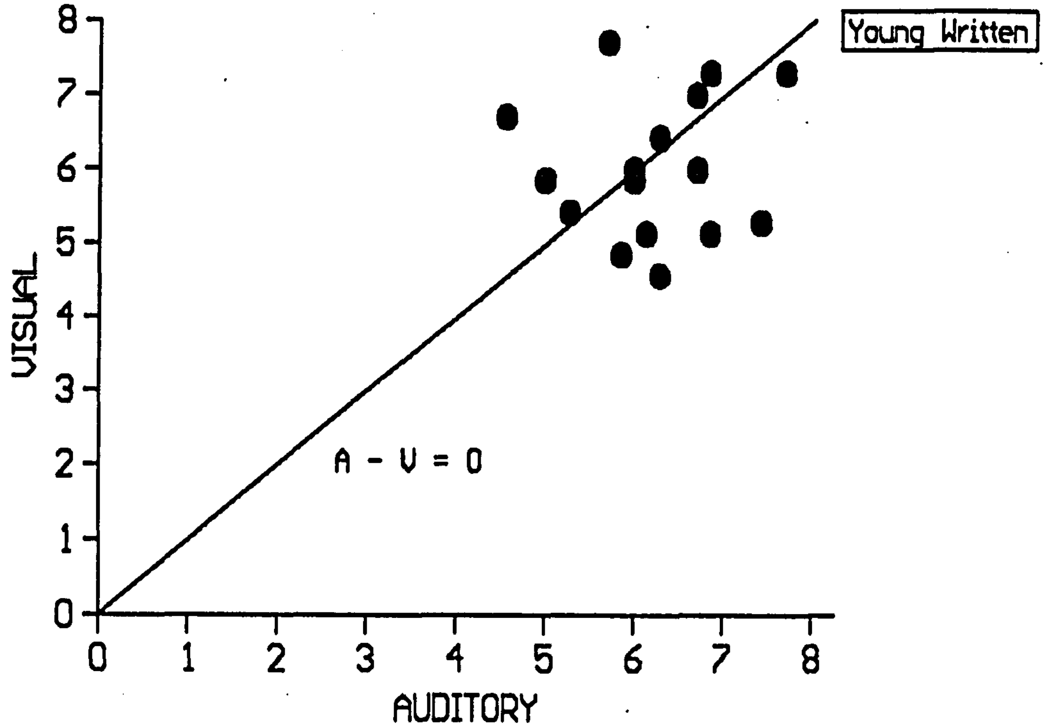
Scatter plots of auditory and visual scores in each recall mode are displayed for young subjects in Figure 1.

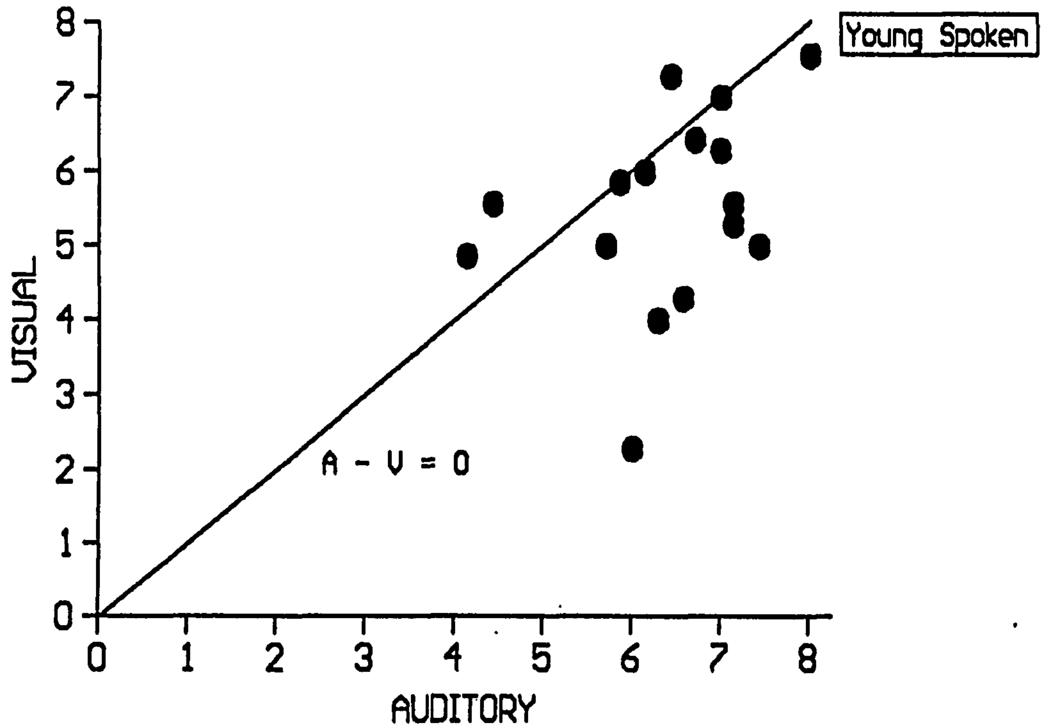
In the written condition, the Spearman $r_{r\ A\ A\text{-}X}$ = .566 and $r_{r\ X\ A\text{-}X}$ = -.70, both of which are significant, indicated that DS had a visual as well as an auditory loading. An inspection of the data showed that these subjects were of four types: First, there were those who had high auditory and high visual scores, resulting in a low DS, those who had high auditory and low visual scores, resulting in a high DS, those who had low auditory and high visual scores, resulting in a low difference score (i.e., a negative score, since DS = A-V). Finally, there were those individuals who had low auditory and low visual scores, resulting in a low DS. For this group the DS fluctuation is associated with both auditory and visual performance in this recall condition. Or, as visual performance improves, the DS decreases, and as auditory performance improves, the DS gets larger.

In the spoken condition, the results for the young showed $r_{r\ A\ A\text{-}X}$ to be .40 and $r_{r\ X\ A\text{-}X}$ to be -.589, only the latter being significant. However, the same trend as exists in the written data appears to be present here.

For elderly subjects the scatter plots of the DS's are

Figure 1. Auditory and Visual Scores for Young Subjects.


Young Written
VISUAL
AUDITORY
A - V = 0
0
1
2
3
4
5
6
7
8

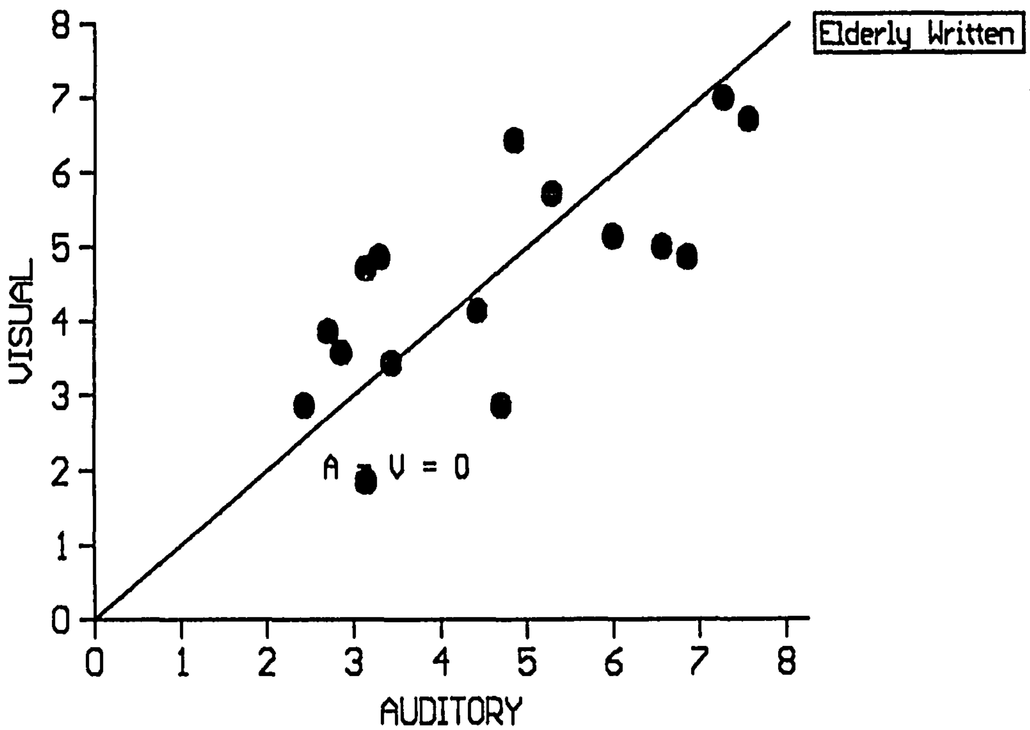

Young Spoken
VISUAL
AUDITORY
A - V = 0
0
1
2
3
4
5
6
7
8

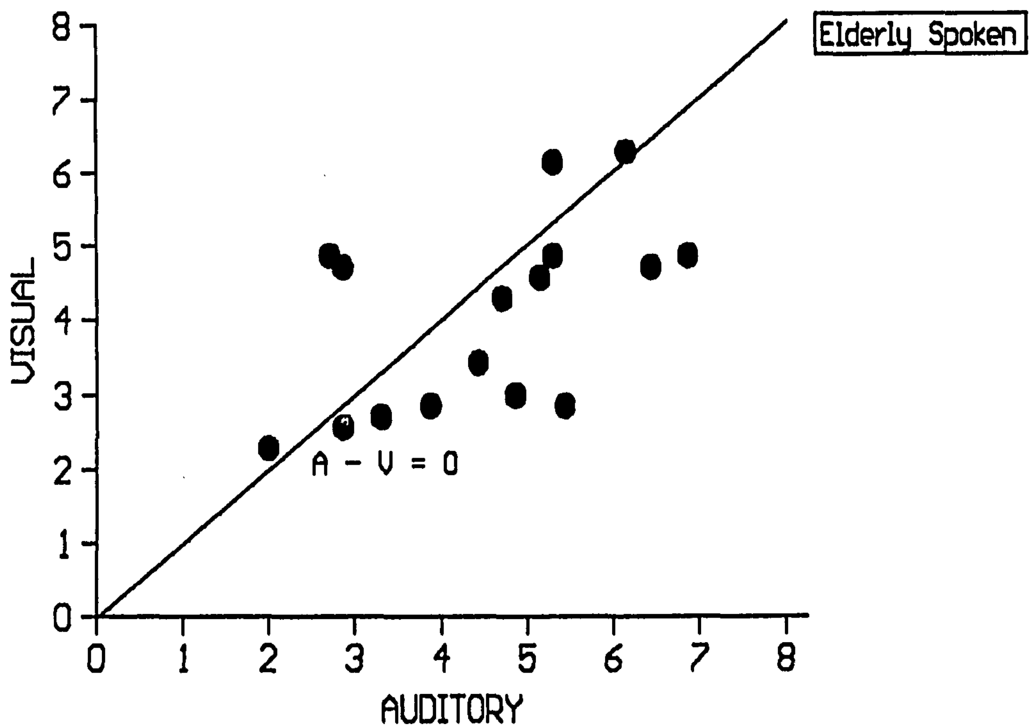
shown in Figure 2.

In the written condition, the Spearman calculations yielded $r_{r\,A\,A-X}$ = .31 and $r_{r\,X\,A-X}$ = -.04. The former, although not significant, shows a trend toward a heavier auditory than visual loading of the DS. In the spoken condition, $r_{r\,A\,A-X}$ = .46, and $r_{r\,X\,A-X}$ = -.20, neither of which are significant. The latter is suggestive of a small visual loading of the DS.

In order to independently assess auditory and visual superiority, in the written recall condition subjects in each age were sub-grouped according to whether they performed better in the auditory or visual modality. With regard to the elderly, 8 subjects had auditory scores which were higher than their visual scores, 7 had visual scores that were higher than their auditory and one subject was equal in both. T - tests were performed to determine if the auditory scores of those who did better auditorily were significantly better than the auditory scores of those who did better visually. That is, were individuals who were auditorily superior with regard to their own performance auditorily superior to the others? As would be expected, they were: $t(13) = 3.24$, $p < .01$. Next, t - tests were performed to see if the visual scores of those who did better in the visual condition were superior to the visual scores of those who did better in the auditory condition. They were not, $t(13) = .157$, indicating that the apparent

Figure 2. Auditory and visual Scores for elderly subjects.


Elderly Written
VISUAL
AUDITORY
A - V = 0
0 1 2 3 4 5 6 7 8


Elderly Spoken
VISUAL
AUDITORY
A - V = 0
0 1 2 3 4 5 6 7 8

visual superiority of this sub group was really an auditory deficit. Lacking true visual superiority, the positive $\underline{r}_{r\,A\,A-X}$ correlation obtained in this written condition, i.e., the auditory loading of the DS, makes sense in terms of auditory superiority.

For the young in the written condition, $\underline{t}$ - tests of this sort were also performed, although the $\underline{n}$'s of the groups were more uneven, 9 subjects having done better in the auditory condition, and 6 in the visual. As with the elderly subjects, the auditory scores of those who did better in the auditory condition were significantly better than those who did better in the visual, $t(13) = 2.11$, $\underline{p} < .05$. Unlike the elderly though, those who did better in the visual mode had significantly better visual scores than those who did better in the auditory mode. That is, in the written condition, the whole group consisted of a sub group of individuals who were truly auditorily superior as well as a sub group of individuals who were truly visually superior. These findings support the significant positive and negative correlations of auditory as well as visual performance with the DS, i.e., the loading of both factors on the DS.

In the spoken condition, the elderly group had 11 who did better in the auditory mode and only five who did better in the visual mode. Likewise, the young showed an imbalance, with 11 who did better in the auditory mode, 3 who did better in the visual mode and two who performed equally well in both modalities. However, the same comparisons with respect to auditory and visual superiority were made.

For the young, the auditory scores of those who had superior auditory performance were significantly better than the auditory scores of those who did better in the visual condition, $t(12) = 3.30$, $p < .01$. However, the visual scores of those who did better in the visual condition were not superior to the visual scores of those who did better in the auditory condition, $t(12) = .72$, $p > .05$. Of course it is difficult to draw any conclusions given an n of 3 in the visual superiority group, and in light of the corresponding $r_{T\ A\ A-X}$ and $r_{T\ X\ A-X}$, which indicated visual loading and a trend toward auditory loading of the DS for this spoken condition, this result is unclear.

For the elderly comparisons in this condition, neither auditory nor visual superiorities were established, $t(14) = 1.35$, $p > .05$, and $t(14) = -1.73$, $p > .05$, respectively. Again, the n of the visual superiority group was only 5, while that of the auditorily superior group was 11, and apart from noting that no strong loading patterns were indicated by the corresponding $r_{T\ A\ A-X}$ and $r_{T\ X\ A-X}$.

Recall Method

As stated above, there was a marginally significant main effect of Recall Method, written performance having been better than spoken, in general. This superiority of the written condition is located in the significant Recall X Modality interaction (also cited above), wherein performance was equivalent for both recall conditions in the auditory modality, but was superior for written recall in the visual modality. This is, in part, as was predicted: although recoding to the visual or written response mode from the auditory modality caused no difference in performance with respect to the oral response mode, which involved little if any recoding, apparently requiring subjects to recode visually presented stimuli to an oral format depressed recall in comparison to that of the written condition, which required a minimal amount of recoding. Apparently, the availability of subvocal rehearsal, or perhaps the ineffectiveness thereof, did not ease the recoding to an oral format.

Suffix Effects

A second ANOVA was performed with the suffix data, displayed in Table 2. The 2 (Age) X 2 (Recall) X 2 (Modality) X 2 (Suffix) X 7 (Position) ANOVA yielded significant main effects of Age, $F(1,30) = 20.08$, $MS_e = 53.77$, $p = .001$; Modality, $F(1,30) = 5.25$, $MS_e = 13.24$, $p = .0291$; Suffix, $F(1,30) = 89.22$, $MS_e = 4.59$, $p < .00001$; and Position, $F(6,180) = 108.53$, $MS_e = 2.99$, $p < .000011$. These main effects reflected superior recall performance by the young, better overall performance in the visual modality due

Table 2

Mean Number of Correct Responses for Young and Elderly Subjects as a Function of Modality, Recall Method, Suffix and Position in Experiment 1

	Serial Position							
Young	1	2	3	4	5	6	7	M
Written								
Aud. Control	7.38*	6.69*	5.88*	5.19*	5.31*	5.50*	7.56*	6.21
Aud. Suffix	6.56	4.81	4.31	4.06	3.38	2.88	3.44	4.21
Vis. Control	7.50	7.12	6.50	5.62	5.50	5.06	4.94	6.04
Vis. Suffix	7.50	6.81	6.62	5.38	5.12	5.00	5.62	6.00
Spoken								
Aud. Control	7.56	6.56*	6.12*	5.62*	5.75*	5.94*	7.06*	6.36
Aud. Suffix	6.94	5.25	4.62	4.50	3.38	3.19	3.62	4.50
Vis. Control	7.37	6.44	5.75	5.12	4.56	4.62	4.75	5.52
Vis. Suffix	7.31	6.31	6.19	5.19	4.56	4.00	4.69	5.46
Elderly								
Written								
Aud. Control	6.38*	4.88*	4.44*	4.38*	3.56*	3.81*	5.19*	4.66
Aud. Suffix	5.44	3.19	2.94	2.69	2.38	2.00	1.19	2.83
Vis. Control	6.63	5.81	5.25	4.44	3.81	3.00	3.00	4.56
Vis. Suffix	7.12	5.44	4.94	4.19	3.56	2.94	2.88	4.43
Spoken								
Aud. Control	6.75*	5.13	4.06	3.69*	3.13*	3.81*	5.00*	4.50
Aud. Suffix	5.94	3.81	3.62	3.19	2.12	2.25	1.75	3.24
Vis. Control	6.88*	5.44	4.31	3.69	3.06	2.56*	2.50*	4.06
Vis. Suffix	6.13	4.98	4.44	3.50	2.69	1.88	1.63	3.59

Note. * Denotes a significant Dunnet test; C-E = .65.

to the selective disturbance of the auditory recall by the suffix, better recall for both groups in the control than in the suffix condition, and the usual serial position effects. Note that a marginally significant effect of Recall Method, $F(1,30) = 3.31$, $p = .0788$, $MS_e = 6.02$ was obtained, written recall being superior to the spoken.

The following significant two way interactions were obtained: Age X Position, $F(6,180) = 4.16$, $MS_e = 2.99$, $p = .0001$); Recall Method X Modality, $F(1,30) = 13.82$, $MS_e = 4.92$, $p = .0008$; Modality X Suffix, $F(1,30) = 56.61$, $MS_e = 4.93$, $p < .00001$; Modality X Position, $F(6,180) = 13.26$, $MS_e = 1.55$, $p < .00001$, and Suffix X Position, $F(6,180) = 15.29$, $MS_e = 1.05$, $p < .00001$). These were due, respectively, to the inferior performance of the elderly as compared to the young at the later list positions, to written recall being approximately equal to the spoken in the auditory mode, but superior to spoken in the visual modality, to the suffix having exerted its greatest negative effect in the auditory rather than in the visual modality, to modality based positional differences in performance, and to the suffix exerting its greatest effect at later positions.

In addition, a significant three way interaction of Modality X Suffix X Position, $F(6,180) = 12.46$, $MS_e = 1.18$, $p =.0000$, was due to strong end-of-sequence suffix effects in the auditory rather than in the visual modality. A marginally significant Modality X Recall Method X Suffix interaction, $F(1,30) = 3.05$, $MS_e = 7.9$, $p = .0910$, denotes a trend: In both written and spoken recall conditions, for the auditory modality, the suffix exerts equally negative effects on recall. However, in the spoken recall condition in the visual modality, the recall under the suffix condition is somewhat negatively affected, while under the written condition it is almost unchanged from the control.

Recency and Modality Effects Under the Suffix For young subjects, auditory recency was only marginally significant under the suffix in the written condition, $t(15) = -1.78$, $p < .05$. For the spoken, there was no significant recency effect, $t(15) = -1.44$, $p < .05$. Again, in the visual condition, no visual recency was obtained for either the written $t(15) = -1.67$, $p > .05$; or spoken $t(15) = -1.88$, $p > .05$ condition.

Elderly subjects' recency in the auditory condition was also eliminated to the point where performance at position 6 was significantly better than at position 7 for both written, $t(15) = 2.93$, $p < .01$, and spoken, $t(15) = 2.07$, $p < .01$, recall conditions. However, no significant differences were found at these positions for the visual written, $t(15) = .186$, $p > .05$, and visual spoken, $t(15) = -.745$, $p > .05$, conditions.

In order to determine if the reduction in auditory recency was greater for the young than for the elderly, independent t - tests were performed and indicated that elderly showed a significantly greater loss of recency in both the written and spoken conditions, $t(30) = -3.27$, $p < .01$, and $t(30) = -2.42$, $p < .01$, respectively.

To assess the difference between suffix and control performance at each serial position, Dunnet tests, using the pooled error term for Age x Recall x Modality x Suffix x Position were calculated; C - E = .65. An inspection of the recall data of the young subjects (table 2) shows the powerful effect of the suffix in the auditory condition, as evidenced by the significant difference between control and suffix conditions at all positions in the written recall condition, and at positions 2 through 8 in the spoken condition. Also note that there are no significant differences in performance between control and suffix conditions in the visual modality in either written or spoken recall.

For elderly subjects, all positions in the auditory modality in the written recall conditions were significantly affected by the suffix. For the spoken recall condition, five of the seven positions were negatively affected.In addition, under spoken recall, elderly subjects showed a significant difference in visual performance between control and suffix at positions 1, 6 and 7, although these differences were smaller than those effected by the suffix in the auditory condition.

Between age group comparisons of terminal and preterminal suffix effects were performed. For the assessment of preterminal effects, a mean of performances at positions 1 through 6 was calculated for both the control and the suffix conditions and the differences between these means was obtained for each subject. T - tests were then performed comparing the differences between age groups. No significant differences in preterminal effects were found for either auditory written, $t(30) = .38$; visual written, $t(30) = .84$, auditory spoken, $t(30) = 1.74$; or visual spoken, $t(30) = -1.35$, conditions.

For terminal suffix effects, the differences between the control and suffix mean performance at position 7 were obtained. T tests of these differences were made between age groups, and showed no significant differences in suffix effects for auditory written, $t(30) = -.16$; visual written, $t(30) = .84$; auditory spoken, $t(30) = -.36$; or visual spoken, $t(30) = -1.35$, conditions.

Thus, all of the standard effects are evident for both groups. While the predicted interaction of Age with Suffix and Modality was not significant in the Analysis of Variance, modality specific age related differences were evident in so far as the elderly were somewhat susceptible to the visual suffix in the spoken recall condition. This will be discussed further below.

Finally, for the auditory modality, a suffix interference score (SI) was computed by subtracting the overall suffix performance from the overall control performance for each subject for both modalities and recall conditions. Rank order correlations were performed between control (c) and the SI (c - s) score. The highest score and the highest SI were given ranks of "1". Young performance in the control condition was not correlated with SI in either the written ($r_r = -.244$, $p > .05$) or spoken ($r_r = -.015$, $p > .05$) recall condition. The elderly, in both the written and spoken conditions, showed significant positive correlations $r_{r\ \gamma\ \gamma-\gamma} = .625$, $p < .05$, and $r_{r\ \gamma\ \gamma-\gamma} = .593$, $p < .05$, respectively. This means that a high SI is associated with a high auditory control score, and a low SI is associated with a low control performance, indicating only that the detrimental effect of the suffix was more easily seen in elderly subjects with good auditory control performance and was less evident in those with a poor control performance.

Recall Method Under the Suffix

As in the control condition and as reported above, Recall Method interacted significantly with Modality: in the auditory condition, written recall was approximately equal to the spoken, while in the visual condition, written recall was superior to spoken recall.

Intrusion Errors

As the data were being scored, it became evident that a number of young, and a larger number of the elderly, had made a number of intrusion errors. Although relatively small in number, the character of the intrusion errors and the apparent age related differences in the commission thereof were studied. Intrusion errors for both age groups under each recall condition and modality and are displayed in Table 3.

The intrusions were of two types: suffix intrusions consisting of the suffixes "y" and "v", and non-suffix or extra-list intrusions, defined as any letters recalled other than the those included in the experiment. Given that half of the subjects received the suffix condition first, it was possible that some of them had made suffix intrusions even in the control conditions. However, suffix intrusions did not cross over to the control condition for either age group.

A 2(Age) X 2(Modality) X 2 (Suffix) X 2(Recall) ANOVA was performed on the data, yielding significant main effects of Age, $F(1,30) = 6.27$, $MS_e = 2.17$, $p = .0179$ and Suffix, $F(1,30) = 18.16$, $MS_e = .294$, $p = .0002$. These were due to the larger number of intrusion errors made by the elderly, and the greater number of these errors that occurred under the Suffix conditions, respectively.

A significant interaction of Age X Suffix was obtained, $F(1,30) = 8.29$, $MS_e = .294$, $p = .0073$, attributable to the elderly showing a greater increase in the number of intrusion errors in the suffix as compared to the control

Table 3

Number of Intrusion Errors for the Young and Elderly, and the Proportion of Subjects Generating Them in Experiment 1

	Young	Proportion with errors	Elderly	Proportion with errors
Written				
Auditory Control	0	-	3	.19
Auditory Suffix	5	.19	7	.25
Visual Control	1	.06	5	.19
Visual Suffix	1	.06	13	.50
Spoken				
Auditory Control	0	-	7	.13
Auditory Suffix	1	.06	2	.75
Visual Control	0	-	3	.19
Visual Suffix	0	-	8	.25

Note. N for each group is 16.

conditions than did the young.

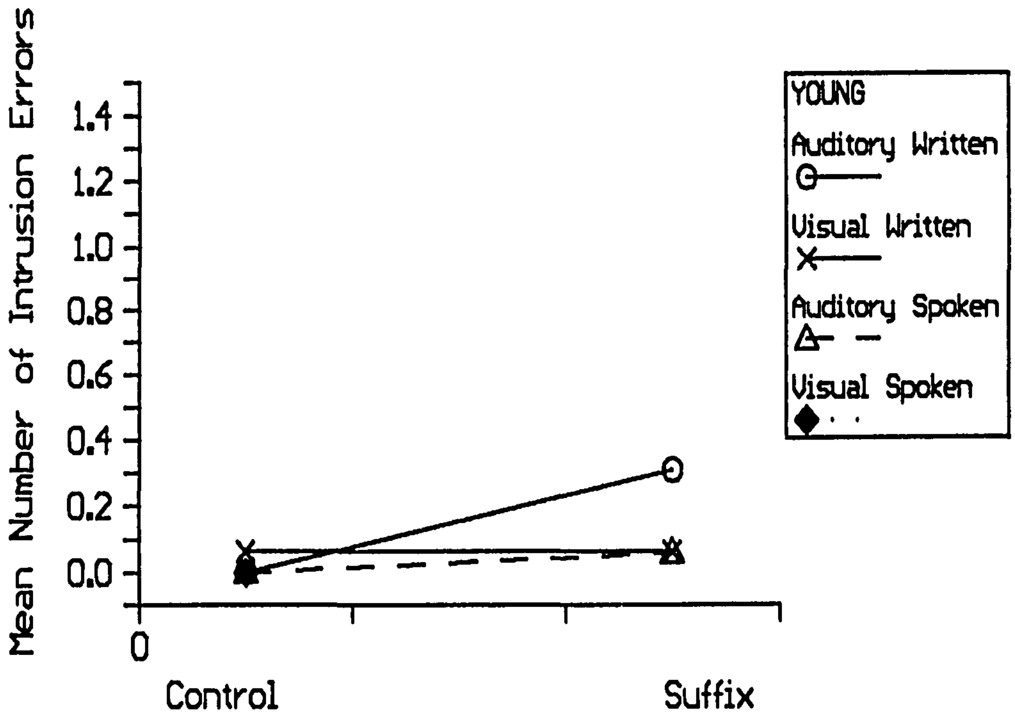
An Age X Modality X Recall Method interaction was significant, $F(1,30) = 5.44$, $MS_e = .52$, $p = .0266$, as was the interaction of Age X Modality X Suffix X Recall, $F(1,30) = 6.54$, $MS_e = .173$, $p = .0159$; Figure 3 depicts the four-way interaction.

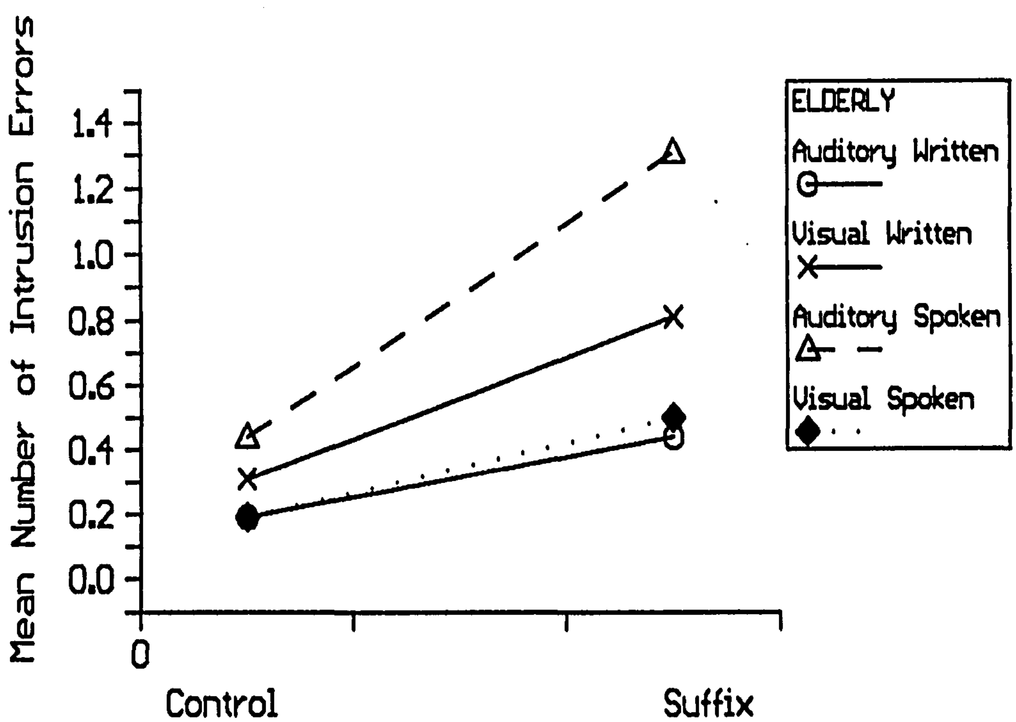
Young subjects, in the auditory modality, showed a slightly greater increase in the number of intrusions between the control and suffix condition when recall was written than when it was spoken. In the visual modality, there was virtually no difference between control and suffix in either recall method; there were no intrusions in visual spoken recall. For the elderly, in the auditory condition, there was an increase in intrusion errors between the control and suffix conditions in written recall, the larger increase being in spoken recall. In the visual modality, intrusion errors increased in control and suffix conditions in both recall conditions and the increases were not as disparate in the auditory condition.

Thus, in general, the elderly were more likely to make intrusion errors than were the young, and were most likely to do so in the auditory condition with a suffixed list, when they were required to respond orally.

In tabulating these errors it became apparent that the extra-list suffix intrusions were of three types: those which were related by sound to the letters for which they

Figure 3. Intrusion errors for young and elderly as a function of Modality, Suffix, and Recall Method in Experiment 1.


Mean Number of Intrusion Errors
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
0
Control
Suffix
YOUNG
Auditory Written
Visual Written
Auditory Spoken
Visual Spoken


Mean Number of Intrusion Errors
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
0
Control
Suffix
ELDERLY
Auditory Written
Visual Written
Auditory Spoken
Visual Spoken

were substituted or to the letters immediately preceding or following them in the alphabet, those that were related by their positions in the alphabet, and those which were seemingly unrelated. For example, the letter "K" was by far the most intrusive, having occurred a total number of 22 times in the elderly data. It was often substituted in the list for the letter "J"; a few times it took the place of the letter "Q". Additionally, quite often "K" would be substituted for a letter which followed "J," in the series, or for a letter which preceded the letter "L" (e.g., if the series was "J, R...." a "J, K...." would be recorded. Similarly, if the series was "R, L....", a "K, L...." might be recorded). Another example of this was found in the substitution of the letter "U" for a letter in the series that immediately followed "Q". Thus, these intrusion errors were phonological and/or alphabetic order based.

The breakdown of intrusion errors into suffix and extra list intrusion types is shown in Table 4.
Apart from the elderly having a far greater percentage of suffix intrusion errors than the young, note that the largest percentage of suffix intrusion errors were made in the spoken recall conditions. Possible reasons will be given below.

Discussion

Although young subjects showed an overall superior recall compared to the elderly, for the most part, both age

Table 4

Suffix Intrusions for Young and Elderly Subjects in the Suffix Conditions of Experiment 1

Young	Intrusions	As Proportion of Total Intrusions
Written Recall		
Auditory	3	.60
Visual	0	-
Spoken Recall		
Auditory	0	-
Visual	0	-
Elderly		
Written Recall		
Auditory	2	.28
Visual	2	.15
Spoken Recall		
Auditory	11	.52
Visual	6	.75

Note. N = 16.

groups exhibited standard serial recall performance in the control condition. The fact that the age difference increased significantly at later positions, despite there being no significant difference between letter spans, supports Taub (1972, 1975) who showed that equating young and elderly for forward digit span did not ensure comparable performance on other span tasks. Parkinson and Perey (1980) on the other hand, claim that no significant age differences in serial recall of suffixed and non-suffixed lists exist when both age groups are equated for performance. (However, see Manning and Greenhut [1990] for a discussion of difficulties with these data.) Clearly other factors, perhaps attentional in nature, are at work here. Perhaps the inability to sustain this span length may play a part in the elderly's overall poorer end of sequence performance.

With regard to modality, no widespread age related differences emerged as they did in Manning and Greenhut (1990). This may in part be due to the fact that the auditory condition in the present study is more properly described as auditory-visual, with subjects actively producing the auditory signal by reading the stimulus aloud. In one sense, dual modality presentation might have served to enhance auditory recall for the elderly to the extent that the age related differences between the modalities would be diminished.

It should be noted that although age related modality differences have been reported, (see for example, Mc Ghie, Chapman and Lawson [1965]), others have failed to show they exist (Taub, 1975).

Although neither group showed sustained significant superiority of either modality across all positions, the loading of the DS on visual and auditory factors did show age differences, while that of the Manning and Greenhut (1990) study did not. Specifically, the DS in the latter work showed a significant negative correlation with visual performance of both age groups; large DSs were associated with poor visual performance. In the present study the interpretation of these differences is somewhat difficult. Young subjects showed both an auditory and visual loading on the DS; individuals were either truly auditorily or visually superior in their recall. This fits with the notion that young subjects may be more fluid, more variable than the elderly in their coding processes. On the other hand, the elderly subjects' trend toward higher loading of auditory performance on the DS may be indicative of their greater dependence on auditory coding.

The interaction of modality and recall method and the nature of the interaction suggest that recoding responses from auditory presentation to written response may not be as difficult as recoding visual presentations to oral responses. Additionally, it indicates that caution is warranted when generalizing findings to studies in which recall methods may vary.

In terms of the suffix, both groups showed fairly typical effects, with the major disruption located in the auditory performance for both groups in equal amount. However, the differences between control and experimental performances at several positions that emerged in the visual modality, spoken recall condition for the elderly may indicate that for this age group, in this recall condition, the suffix is having a negative effect. If the suffix interference were merely a function of encoding the extra item phonologically, as the above stated hypothesis suggests may be the case, then one would expect the suffix effect to appear in the visual written condition as well. As this was not the case, most probably the suffix interference resulted from recoding of the string, along with the suffix, into the oral response mode. Although it should be noted that in the visual written condition, the presence of 7 lines on the answer sheet might have facilitated exclusion of the suffix.

These data may have important implications when assessing elderly recall with tasks in which they are required to read material aloud and report it orally. As noted earlier, it seems that the elderly have a greater problem with the suffix when responding cross modally.

These data also suggest that the elderly are less able to exclude the suffix than are the young. Thus, diminished response inhibition is suggested.

While age did not interact with suffix in the large ANOVA, there was a positive correlation of suffix interference with auditory control scores in the elderly group. Apart from suggesting that a floor effect may be partially responsible for the lack of a suffix-age interaction, more likely it is indicative of a greater susceptibility to suffix interference on the part of these elderly subjects. This might be expected, if most of one's coding resources are spent on one method, i.e., phonological coding.

Finally, some very important age differences were seen with respect to intrusion errors. Hasher and Zacks (1988) state that the reduced capacity model of aging memory has some serious drawbacks which they enumerate carefully and convincingly. They describe research and argue that the age related decline in working and primary memory is related to the increasing inability of elderly persons to filter irrelevant information and to inhibit responses. The present finding that older adults made significantly more intrusions than the young is supportive of this. (See also McDowd et al., 1991). Hasher and Zacks (1988) suggest that the failure to filter may be related to irrelevant thoughts, i.e., some sort of internally generated noise that compete with the processing task at hand. The phonological and alphabetic order bases of the extra list intrusions also suggests that this internally generated noise may be auditory/articulatory in nature. The greater number and nature of intrusion errors made by the elderly suggests that this group may experience this internal noise to a greater degree than the young.

Welford (1985) proposes that a discrimination model of memory and learning in which these tasks are understood in terms of the various signal-to-noise ratios and accuracy criteria involved is useful, especially in understanding age differences in short term memory. In list learning tasks, for both encoding and recall, it is necessary to distinguish the list items that are very similar in associations and meanings from previously stored items. For this to be done successfully, the list item traces must be coded as such; if this code or label of "list item" is sufficiently strong (strong signal), or the background noise is sufficiently weak, than this task is easier and a criterion of accuracy may be set which is reflected by the types of errors committed.

In recognition memory tasks, the signal-to-noise ratio is lower, due to there being less background noise. That is, the items from which they must distinguish the signal are relatively few and present for inspection, in comparison with a recall paradigm, in which the signal may be embedded in a large, multidimensional array of items, which are not physically present for inspection. Welford (1985) notes that elderly recognition memory does not suffer as much as that of recall.

The intrusion errors committed here suggest the possibility that a higher signal-to-noise ratio exists for the young than for the elderly. Of course only a signal detection analysis would confirm this.

It is interesting to note that in Manning and Greenhut - Wertz (1990), elderly subjects made no intrusion errors in either modality. Other short term memory studies show that normal elderly subjects make few, if any intrusion errors (See, for example, Shindler, Caplan and Hier, 1984), while demented elderly often do produce such errors (Mackell, 1993; Shindler et al, 1984). However, Hartikainen, Soinen, Patanen, Helkala and Riekkinen (1992) demonstrated intrusion errors with a list learning task in normal subjects aged 80 to 92 years.

In the present study, although not very numerous, these errors were substantially different in number for the two age groups.

The question arises as to why the present study showed intrusion errors while the Manning and Greenhut-Wertz study did not. Of course, one reason is that the Manning and Greenhut-Wertz study did not employ spoken recall, which resulted in the greatest number of intrusions for the elderly in the auditory condition. Equally important is a procedural difference in the two studies with regard to the collection of written data: In Manning and Greenhut (1990), one standard answer sheet, for the recording of all list, was used. Therefore, previously written lists were available for inspection by the subjects. Indeed, as was noted earlier, many elderly subjects were observed to be reviewing their previously written lists. Of course, this would not help them in recalling the order of the letters, hence their performance still suffered. However, it is possible that the availability of the list letters for review reduced the signal-to-noise ratio much in the same way a recognition memory task does, by reducing the background noise.

In the present study, oral recall did not allow subjects to review the list letters. Moreover, the written recall condition did not provide a review of previously recorded lists, since subjects recorded a list on a page in the answer booklet and then turned it, which prevented review of the previously recorded answers. Thus, a type of compensatory opportunity, which even high functioning elderly may utilize, was not available. In our opinion, it was this inability to verify list items that unmasked the intrusions of "noise" into the response set.

Finally, these data also underscore the usefulness of the suffix paradigm in uncovering age related differences that are qualitative as well as quantitative.

Experiment 2

Young and elderly subjects participated in a study which employed the same basic stimuli and procedures, and which also included a "pure" auditory condition. However, since the study was originally conceived as including another paradigm (discussed later in this paper) each subject participated in one modality condition only, in order to ensure that the experimental session was not excessively long or tiring. In addition, the two suffixes employed here were the letters "F" and "P", both of which had been chosen because of their potential auditory and visual confusion with two of the letters, "S" and "R" in the stimuli lists. It was thought that if the coding of the suffix was auditory, then the suffix "F" would be more detrimental to performance, and might be substituted for "S" more than "P" would be substituted for "R". In the event of visual processing the opposite situation would obtain.

In addition, these letters were not located at the end of the alphabet, which would make them more difficult to exclude from the sequence than those that are; letters such as "X", "Y" and "Z" may be more distinctive than other letters by virtue of their less frequent occurrence in everyday language and also because they are end letters connoting the end of a sequence, and thus may be less intrusive. Since elderly subjects may be less efficient in filtering irrelevant stimuli, these suffixes were thought to provide a more challenging task for this group.

Overall superiority of the young performance should again emerge; passive auditory recall may better delineate any relatively greater age differences in the auditory modality. With regard to type of recall, written should be better than spoken in the visual condition and spoken should be best in the passive auditory condition.

Results for each modality will be given separately.

The Auditory Condition

Method

Subjects. Twelve young (nine females, three males) and elderly subjects (eleven females, one male), were drawn from the same Hunter College population. The young ranged in age from 18 to 31 years, with a mean age of 25.08. The elderly age range was 65 to 78 years, with a mean age of 71.4 years. All participated on a voluntary basis.

Elderly subjects were well educated with a mean of 15.88 years of education. Mini-mental scores averaged 29.66, and the mean letter span was 6.0 letters. All subjects reported that they were able to hear the stimuli quite well.

Young subjects were primarily undergraduates with 14.41 mean years of education. Mini-mental scores averaged 29.83, and their mean letter span was 6.46. Again, all subjects reported they were able to hear the stimuli well.

Stimuli and Experimental Design. Seven letter sequences consisting of the uppercase letters J,Q,R,L,M,S,H (as in experiment 1) were randomly assembled with the restriction that the target letters "S" and "R" appear in each position equally often. Four lists consisting of eight of those sequences were constructed. The suffixes were the uppercase letters "F" and "P" which were assigned randomly but equally to the sequences within a particular list. Twelve different list orders were determined by a balanced 12 X 12 latin square; each list represented a block of trials.

Half of the subjects received the suffix condition before the control, and half received the spoken recall condition before the written. Subject assignment was random.

Two practice trials were given at the beginning of each condition.

Apparatus and Procedure. The stimulus lists were recorded in a female voice on a Sony TCS 450 stereo cassette recorder at the rate of one letter per second. Stimuli were presented through Stanton Dynaphase I headphones to both ears. In the control condition, the recall signal was a click appended to the list and recorded at the same sound level as the letters. A 20 second response period was allowed, during which time subjects recorded their responses in strict serial recall in booklets which were described in experiment 1. In the spoken recall condition, the experimenter recorded the subjects' responses.

As in the first study, subjects were instructed to regard the click or the suffix as a signal to begin recall, which itself was not to be recalled. Subjects were encouraged to guess if they were not sure of the answer, and no backtracking was allowed.

Results

Table 5 displays the data for all subjects in all conditions.

A 2(Age) X 2(Recall) X 7(Position) ANOVA was performed on the control data, yielding significant main effects of Age, $F(1,22) = 55.40$, $MS_e = 11.65$, $p = .001$ and Position, $F(6,132) = 25.55$, $MS_e = 1.98$, $p = .001$), due, respectively, to the superior recall of the young over the elderly and to the superior recall of both age groups in the first and last list positions. Note that both groups showed typically bow shaped serial recall curves for both recall conditions.

A significant Age X Position interaction, $F(6,132) = 5.70$, $p = .001$, was the result of the inferiority of elderly performance with respect to that of the young in positions two through seven (Dunnett test, C - E = .95).

Recency. Young subjects showed significant recency in both the written, $t(11) = -3.07$, $p < .01$, and the spoken $t(11) = -3.74$, $p < .01$, conditions. Likewise, for elderly subjects, there was significant recency in written, $t(11) = -4.70$, $p < .01$ and spoken $t(11) = -3.83$, $p < .01$, conditions.

Table 5

Mean Number of Correct Responses as a Function of Age, Suffix, Modality and Position in the Auditory Modality (Experiment 2)

	Serial Position							
	1	2	3	4	5	6	7	M
Young								
Written								
Control	7.92	7.50*	7.16	6.83*	6.67*	6.75*	7.75*	7.22
Suffix	7.92	6.75	6.67	6.08	5.42	4.83	5.08	6.11
Spoken								
Control	7.75	7.00	6.25	6.92*	6.08*	6.17*	7.58*	6.82
Suffix	7.33	6.50	6.17	6.08	5.25	5.33	5.17	5.98
Elderly								
Written								
Control	6.83	5.08*	3.00	3.42*	2.92*	3.17*	5.42*	4.26
Suffix	6.58	3.50	2.58	2.75	2.17	1.92	1.00	2.93
Spoken								
Control	7.17*	4.75*	3.83*	3.67*	2.75*	2.83*	4.75*	4.25
Suffix	6.50	3.83	3.00	2.33	1.33	1.25	0.42	2.67

Note. * Denotes a significant Dunnet test; C-E = .67.

Recall Method. No significant differences were found with respect to recall mode.

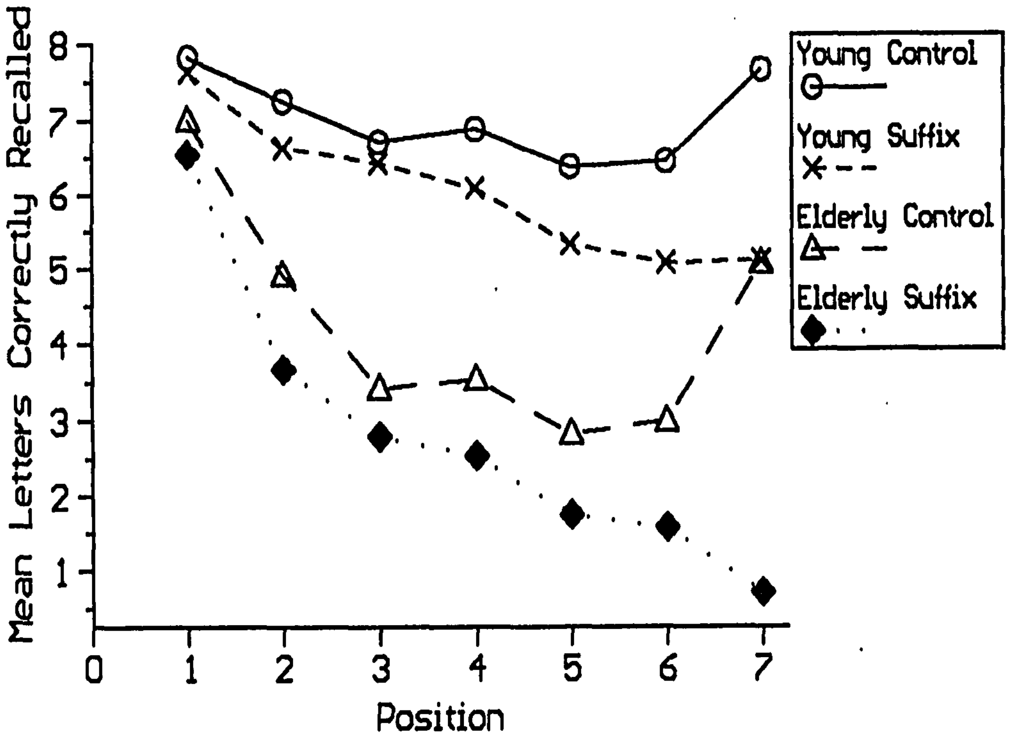
Suffix Effects. A Separate 2(Age) X 2(Suffix) X 2(Recall) X 7(Position) ANOVA was performed, yielding significant main effects of Age $F(1,22) = 74.62$, $MS_e = 20.34$, $p = .0001$; Suffix, $F(1,22) = 55.25$, $MS_e = 4.53$, $p = .0001$ and Position $F(6,132) = 49.34$, $MS_e = 2.41$, $p =.0001$). These were attributed, respectively, to the overall superior performance of the young subjects, the pervasive, detrimental effects of the suffix, and the typical suffix serial recall curve with positional differences due to primacy and suffix effects.

The Suffix X Position interaction, $F(6,132) = 26.75$, $MS_e = .99$, $p =.0000$, and the Age X Position interaction $F(6,132) = 9.10$, $MS_e = 2.41$, $p < .00001$, were significant and can be attributed to the more detrimental effect of the suffix at the later than at the earlier positions, and to an increase in performance difference between the two age groups that begins at the second position, but levels off after the third.

Finally, an Age X Suffix X Position interaction was significant $F(6,132) = 2.41$, $MS_e = .99$, $p = .034$ and is represented in Figure 4, indicating that performance was significantly reduced by the suffix at later positions for the elderly than for the young.

Recency under the Suffix. Recency in both the written

Figure 4. Recall as a function of Age, Suffix, and Position in the auditory condition of Experiment 2.


Mean Letters Correctly Recalled
8
7
6
5
4
3
2
1
0
1
2
3
4
5
6
7
Position
Young Control
Young Suffix
Elderly Control
Elderly Suffix

and spoken recall modes was eliminated for young subjects, $\underline{t}(11) = -.76$, $\underline{p} > .05$, and $\underline{t}(11) = -.61$, $\underline{p} > .05$, respectively. For the elderly, as in Experiment 1, the suffix adversely affected performance at the last position to such a degree that performance at position six was superior to that of position seven, in both written and spoken conditions, $\underline{t}(11) = 3.3$, $\underline{p} < .01$, and $\underline{t}(11) = 3.07$, $\underline{p} < .01$, respectively.

<u>Recall Method under the Suffix.</u> An Age X Recall Method X Position interaction, $\underline{F}(6,132) = 2.46$, $\underline{MS}_e = 1.07$, $\underline{p} = .0274$ was due to a set of irregular results across a variety of conditions, having to due with superiority in performance in different recall modes by each age group at one position only. It is likely that these results are idiosyncratic.

<u>Suffix Types.</u> A 2(Age) X 2(Recall) X 2(Type) X 7 (Position) ANOVA was performed on recall in the suffix condition displayed in Table 6; Maximum number correct at each position is four. Only the findings as related to Suffix Type will be reported as the others have already have been given above.

Suffix Type was significant as a main effect, $\underline{F}(1,22) = 5.96$, $\underline{MS}_e = 1.37$, $\underline{p} = .0231$, the "F" suffix having been more interfering than the "P". However, a significant Age X Type interaction, $\underline{F}(1,22) = 5.64$, $\underline{MS}_e = 1.37$, $\underline{p} = .03$) locates this effect solely in the young performance: "F" recall was

Table 6

Mean Number of Items Correctly Recalled as a Function of Age, Recall Method, and Suffix Type Position in the Auditory Condition.

	Serial Position							
	1	2	3	4	5	6	7	M
Young								
Written								
Suffix F	3.92	3.33	3.17	2.83	2.75	1.83*	2.00*	2.83
Suffix P	3.92	3.33	3.42	3.00	3.00	2.58	3.00	3.18
Spoken								
Suffix F	3.33	2.83*	2.75	2.67*	2.33*	2.50	1.92	2.62
Suffix P	3.75	3.42	3.17	3.25	3.00	2.83	3.08	3.21
Elderly								
Written								
Suffix F	3.33	1.75	1.17	1.42	1.17	0.75	0.50	1.44
Suffix P	3.25	1.83	1.42	1.66	0.92	1.08	0.50	1.52
Spoken								
Suffix F	3.25	2.42*	1.67	1.25	0.42	0.25	0.00	1.32
Suffix P	3.12	1.42	1.25	1.08	0.91	0.83	0.41	1.29

Note. * Denotes significant Dunnett test; C - E = .58.

significantly poorer than "P" recall for this group, while elderly performance was equally poor for both suffixes.

Finally, a significant Type X Position interaction, $\underline{F}(6,132) = 2.85, \underline{MS}_{e} = 1.59, \underline{p} = .012$) was due to recall under the "F" suffix becoming significantly poorer than recall under the "P" suffix at positions six and seven (Dunnett test, not illustrated, using the Suffix Type X Position error term; C - E = .50).

In order to determine if there was a direct relationship between the suffixes and their respective targets, the total number of target errors of each type (S and R errors) in each sequence under spoken and written recall conditions for each subject was tallied. An error was considered to be an omission or a non-target letter occupying the correct position of the target letter. Accordingly, the maximum number of target errors for a particular condition was 16, since the target letters "S" and "R" appeared once in each of the eight sequences that constituted a condition. Although each suffix appeared in a particular condition in half of the lists, both "S" and "R" errors were counted for each suffix.

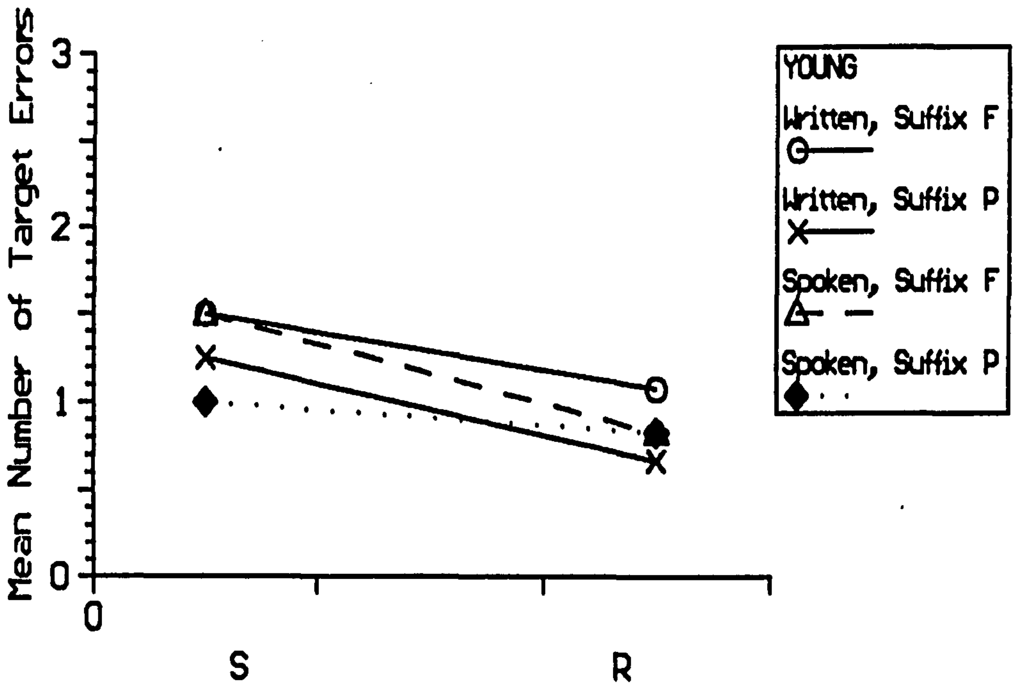
A 2 (Age) X 2 (Recall Method) X 2 (Suffix Type) X 2 (Target Letter Error) ANOVA was performed, yielding significant main effects of Age, $\underline{F}(1,22) = 30.89$, $\underline{MS}_{e} = 2.98$, $\underline{p} < .00001$, and Target Letter Error, $\underline{F}(1,22) = 8.79$, $\underline{MS}_{e} = .900$, $\underline{p} = .0071$. These were due to the elderly having more target errors in general, and to the number of "S" errors having been greater than "P" errors for both groups. Suffix Types did not interact with Target Letter Errors for either age group. While the young subjects performed better under the P than the F suffix, there was little difference in the number of S errors (i.e. those targeted by the F suffix) between these two suffix conditions; S errors were predominant. This may have been due to the letters F, M, S, and L all begin with the same vowel sound and are therefore more confusable. That is, an analysis of M or L errors might show a predominance of these as well. However, the following trend should be noted, and is illustrated in Figure 5: Elderly subjects showed little difference in S and R errors; performance is equally poor in both spoken and written recall conditions.

However, for young subjects, in the written condition, R errors were almost half the number of S errors when the suffix was P. In spoken recall, R errors were almost half those of S errors when the suffix was F. Thus, there seems to be a trend toward differential sensitivity on the part of the young, and less of one on the part of the elderly.

<u>Intrusions.</u> As in the first study, both extra-list and suffix intrusions were tallied. The total number of intrusions for each group in each condition appears in Table 7.

Suffix intrusions were also tallied for the suffix

Figure 5. Target Letter Errors of young and elderly subjects in spoken and written recall conditions in the Auditory modality of Experiment 2.


Mean Number of Target Errors
0
1
2
3
0
S
R
YOUNG
Written, Suffix F
Written, Suffix P
Spoken, Suffix F
Spoken, Suffix P

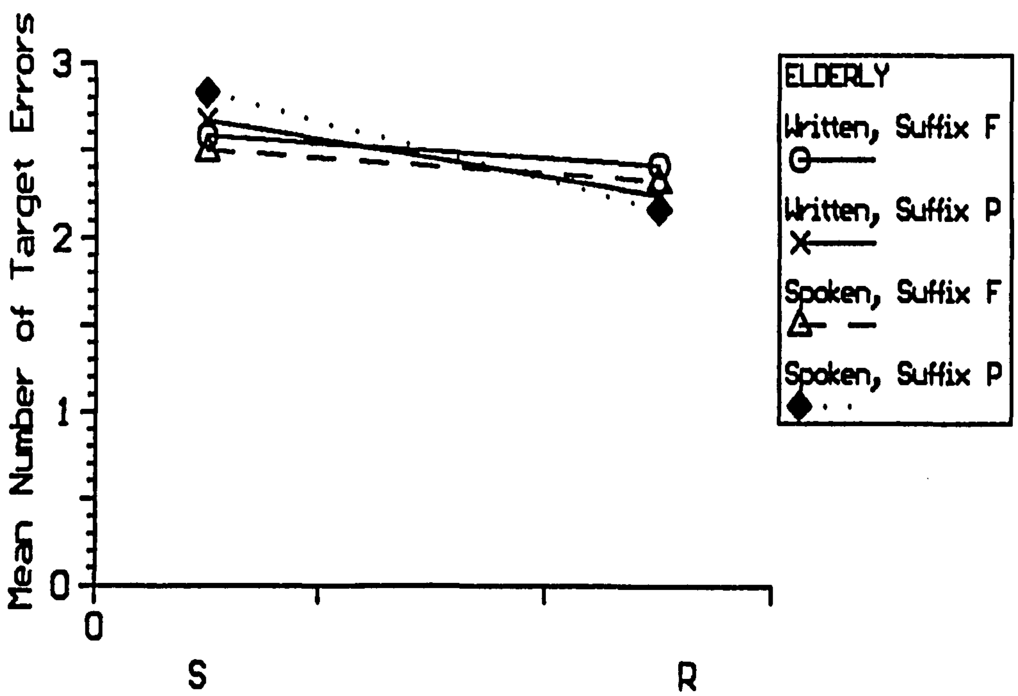

Mean Number of Target Errors
0
1
2
3
0
S
R
ELDERLY
Written, Suffix F
Written, Suffix P
Spoken, Suffix F
Spoken, Suffix P

Table 7

Intrusion Errors for the Young and Elderly, and the Proportion of Subjects Generating Them in the Auditory Condition of Experiment 2.

	Intrusions	Proportion with errors
Young		
Written		
Control Condition	2	.17
Suffix Condition	2	.08
Spoken		
Control Condition	1	.08
Suffix Condition	4	.25
Elderly		
Written		
Control Condition	12	.50
Suffix Condition	30	.67
Spoken		
Control Condition	3	.17
Suffix Condition	15	.50

conditions only, since no suffix intrusions crossed over into the control conditions; these appear in Table 8.

A 2 (Age) X 2 (Suffix) X 2 (Recall Method) was performed, yielding significant main effects of Age, $F(1,22) = 18.95$, $MS_e = 2.62$, $p = .0003$ and Suffix, $F(1,22) = 14.42$, $MS_e = .79$, $p = .001$. These were due to the elderly's greater number of intrusions as compared to young subjects and to the suffix conditions resulting in more intrusions than the control conditions. There was a marginally significant effect of Recall Method, $F(1,22) = 4.01$. $MS_e =1.37$, $p = .0577$, the basis of which is the greater number of intrusions in the written rather than the spoken recall condition.

Age interacted with Suffix, $F(1,22) = 9.65$, $MS_e = .79$, $p = .0051$, and with Recall Method, $F(1,22) = 4.74$, $MS_e = 1.37$, $p = .0405$. These can be attributed to, respectively, the elderly's increase in intrusions under the suffix being greater than that of the young, and a greater number of intrusions in the written as opposed to the spoken recall condition on the part of elderly, but not young, subjects. Intrusion errors were also examined with regard to the list letters ("S" and"R") that were targeted by the suffixes.

For the young in the written condition, neither of the two suffix intrusions were substitutes for the targets. In the spoken condition, the one suffix intrusion was also not a substitute for the target letter. Of 17 suffix-for-letter

Table 8

Suffix Intrusions made by Young and Elderly Subjects in the Suffix Conditions of the Auditory Modality of Experiment 2.

Young	Intrusions	As Proport.of Total Intrusions in Suff.Cond.[a]
Written	2	1.00
Spoken Recall	1	.25
Elderly		
Written	17	.40
Spoken Recall	7	.50

[a]Proportion of the total number of intrusions, i.e. extra - list as well as suffix, in the suffix conditions.

substitutions made by elderly subjects in the written suffix condition, 5 were substitutions of "F" for "S", and 1 was a substitution of "P" for "R". In the spoken suffix condition, of the eight suffix-for-letter substitutions, 1 was "F" for "S".

The Auditory-Visual Condition

Method

Subjects. Again, twelve young (nine female, three male) and elderly (ten female, two male) Hunter College students participated on a voluntary basis. The young subjects ranged in age from 18 to 29.5 years; the mean was 22.79 years. The elderly age range was from 66 to 81 years with a mean of 71.5 years.

Again, elderly subjects were well educated with a mean of 15.65 years of education. The mean mini-mental score was 29.58, and their mean letter span was 6.0 letters.

Young subjects were primarily undergraduate students at the College, with a mean mini-mental score of 29.92 and a mean letter span of 6.75 letters.

No subjects were on medications that would impair performance and none reported difficulty in seeing the stimuli.

Stimuli and Experimental Design. The same stimuli and design used in the auditory portion were employed.

Apparatus and Procedure. The letters were presented on a microcomputer with an 8088 microprocessor and a clock speed of 8mhz. Letters were presented sequentially in the center of the amber monitor at a rate of 1 per second (.5 second on, .5 second off), and there was twenty second interval between sequences during which either the subjects or the experimenter recorded the answers.

Subjects were instructed to read the letters aloud as they appeared on the screen, and in the suffix condition, to read that aloud as well. In the control condition, a dash (-) replaced the suffix, and subjects were instructed to view the dash before beginning recall. They were encouraged to guess if they did not remember the letters, and were told that no back tracking to change or fill in blank spaces was allowed. Two practice trials were given at the beginning of each condition, during which time the experimenter made sure that there was no procedural problem.

Results

The data for all subjects in each condition are presented in Table 9.

A 2 (Age) X 2 (Recall) X 7(Position) ANOVA was performed on the control data, yielding significant main effects of Age $F(1,22) = 25.26$, $MS_e = 21.48$, $p < .00001$ and Position, $F(6,132) = 20.16$, $MSe = 1.68$, $p < .00001$. These were due to the overall superior performance of the young as compared to the elderly, and to the typical inferior performance at the midlist positions for both groups, respectively.

Table 9

Mean Number of Correct Responses as a Function of Age, Suffix, Modality and Position in the Auditory - Visual Modality of Experiment 2

	Serial Position							
	1	2	3	4	5	6	7	M
Young								
Written								
Control	7.58	6.75	6.58	6.67*	6.50*	6.42*	7.75*	6.89
Suffix	7.67	6.92	6.25	5.83	5.17	4.91	4.58	5.90
Spoken								
Control	7.75	6.92	6.67	6.58	6.17*	6.25*	7.17*	6.79
Suffix	7.41	6.58	6.00	6.08	5.08	4.75	5.33	5.89
Elderly								
Written								
Control	6.83*	4.50*	3.42	3.50	2.92*	3.42*	4.67*	4.18
Suffix	5.50	3.50	3.42	3.17	2.17	1.75	1.42	2.99
Spoken								
Control	6.33*	4.83*	4.00*	4.00*	3.42*	2.83*	4.92*	4.42
Suffix	5.50	3.25	2.50	2.42	1.75	1.58	1.42	2.63

Note. * Denotes a significant Dunnet test; C-E = .71.

Age interacted with Position, $F([6,132) = 3.66$, $MS_e = 1.68$, $p = .0022$, and Dunnett tests (calculated using the Age X Position error term; C - E = .87), confirmed that the young performed significantly better than the elderly at every position, and that the age difference was greater at positions 3 through 7 than at the first two positions.

Recency. Young subjects showed superior performance at the final as compared with the penultimate position in both written and spoken conditions, $t(11) = -3.07$, $p < .001$, and t (11) = 1.95, $p < .05$, respectively.

The situation was the same for the elderly, with both written and spoken significant recency, $t(11) = -4.70$, $p < .001$, and $t(11) = -3.83$, $p < .001$.

Recall Method. The mode of recall did not cause significant differences in performance for either age group at any position.

Suffix Condition. A 2(Age) X 2(Suffix) X 2(Recall) X 7(Position) ANOVA showed significant main effects of Age, $F(1,22) = 31.51$, $MS_e = 42.26$, $p < .00001$), Suffix, $F(1,22) = 46.53$, $MS_e = 5.33$, $p < .00001$) and Position $F(6,132) = 44.34$, $MS_e = 1.90$, $p < .00001$, due, respectively, to the overall superiority of the young performance, the detrimental effect of the suffix for both age groups, and the superior performance in the early positions as compared to the mid and last positions, respectively.

As in the above studies, Age interacted with Position,

$\underline{F}(6,132) = 4.04$, $\underline{MS}_e = 1.90$, $\underline{p} =.0000$), as the difference between the age groups increased between positions one and two and again between positions two and three, remaining fairly constant after that.

Suffix also interacted with Position, $\underline{F}\ (6,132) = 11.46$, $\underline{MS}_e = 1.50$, $\underline{p} < .00001$, due to the suffix exerting greater negative effects at the later rather than at the earlier positions.

Note that in the written recall condition, there was little difference with respect to the number of positions at which performance was negatively affected due to the suffix. However, under spoken recall, the performance of the elderly was adversely affected at all positions, while the young suffix effects were relegated to the last three positions in the recall curve. Thus, although a significant interaction of Age, Recall Method, Suffix and Position was not obtained in the overall ANOVA, it is clear that when the elderly had to recall aloud, they had a more difficult time with the suffix at the early list positions than did the young.

Recency under the Suffix. No significant recency effect was found for young subjects in either the written or spoken condition, $\underline{t}(11) = 1.17$ and $\underline{t}(11) = -1.40$, respectively. Similarly, no significant recency was found for elderly subjects in either the written or spoken condition, $\underline{t}(11) = .65$ and $\underline{t}(11) = .33$, respectively.

Suffix Types. Suffix Types data are displayed in

Table 10. These were analyzed as in the Auditory condition, and again, only those results relevant to Types will be reported.

In the Age X Recall Method X Suffix Types X Position ANOVA,there was no main effect of Suffix Type. However, Suffix Type did interact with Age, $F(1,22) = 6.95$, $MS_e = 1.34$, $p = .0151$, due to the young performance in the "P" suffix condition having been better than in the" F", while the opposite situation obtained for the elderly.

The Age X Recall X Type interaction, although not significant, suggested that the superior young "P" performance was located in the written condition; spoken recall for this group showed an approximately equal performance for both suffix Types (although the "F" recall was just slightly better than "P"). The elderly, on the other hand, in both the written and the spoken recall conditions, did only slightly better with the "F" suffix. Thus, it would seem that with the addition of the visual aspect of the stimuli, the F suffix does not prove to be as difficult as in the pure auditory condition.

As in the Auditory Condition, target letter errors were tabulated for both groups and are displayed in Figure 6.

A 2 (Age) X 2 (Recall Method) X 2 (Suffix Type) X 2 (Target Letter Error) was performed. Significant main effects of Age, $F(1,22) = 24.96$, $MS_e = 3.86$, $p = .0001$; Suffix Type, $F(1,22) = 5.90$, $MS_e = .904$, $p = .0238$; and

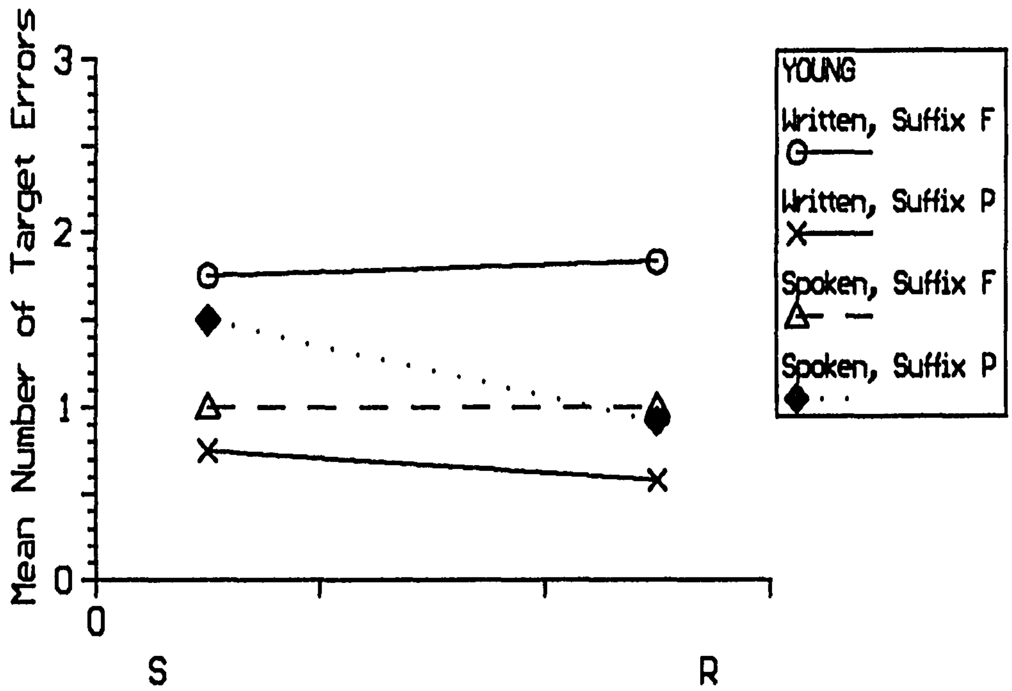
Table 10

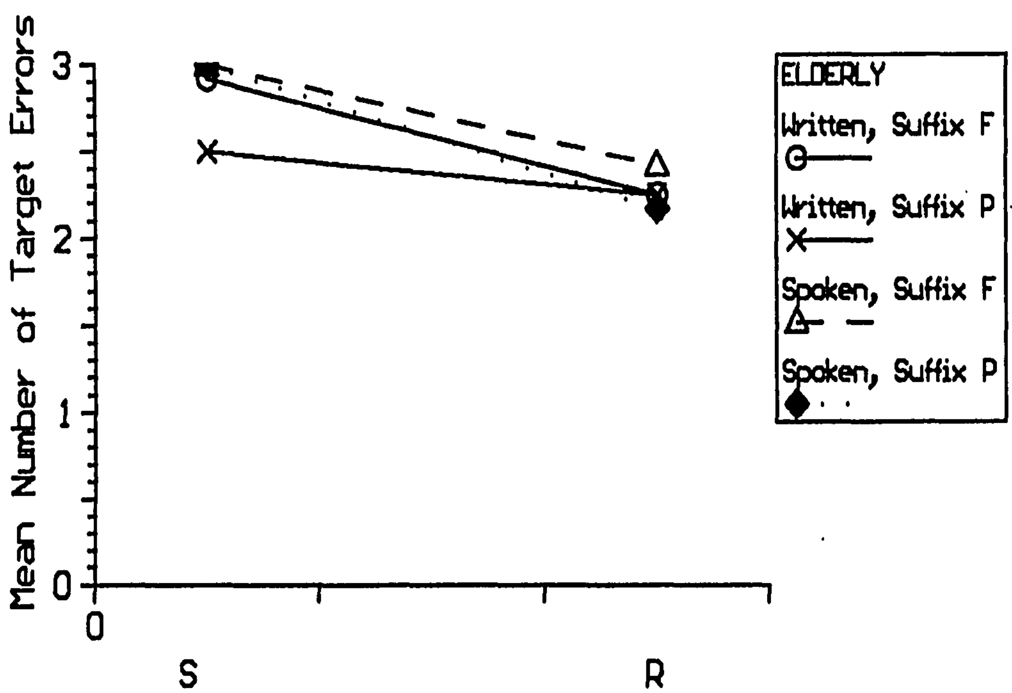
Mean Number of Items Correctly Recalled as a Function of Age, Recall Method, and Suffix Type Position in the Auditory - Visual Condition.

	Serial Position							
	1	2	3	4	5	6	7	M
Young								
Written								
Suffix F	3.83	3.25	3.08	2.58	2.17*	1.92*	2.08*	2.70
Suffix P	3.83	3.67	3.00	3.25	3.00	3.00	3.08	3.26
Spoken								
Suffix F	3.50	3.25	3.33	3.25	2.67	2.42	2.75	3.02
Suffix P	4.00	3.33	2.83	3.00	2.50	2.33	2.58	2.94
Elderly								
Written								
Suffix F	2.67	1.83	1.92	1.67	1.42	0.83	1.17*	1.64
Suffix P	2.83	1.67	1.50	1.50	0.75	0.92	0.58	1.39
Spoken								
Suffix F	2.75	1.75	1.25	1.58	0.92	0.75	0.75	1.39
Suffix P	2.67	1.67	1.17	0.83	0.75	0.75	0.42	1.18

Note. * Denotes significant Dunnett test; C - E = .76.

Figure 6. Target Letter Errors of young and elderly subjects in the Auditory - Visual modality of Experiment 2.


Mean Number of Target Errors
0
1
2
3
0
S
R
YOUNG
Written, Suffix F
Written, Suffix P
Spoken, Suffix F
Spoken, Suffix P


Mean Number of Target Errors
0
1
2
3
0
S
R
ELDERLY
Written, Suffix F
Written, Suffix P
Spoken, Suffix F
Spoken, Suffix P

Target Letter Error, $\underline{F}(1,22) = 19.86$, $\underline{MS}_e = .339$, $\underline{p} = .0002$ were due, respectively, to the elderly having had more target errors than the young, to the greater number of target errors under the F suffix than under the P suffix, and the greater number of S errors as compared to R errors.

Recall Method interacted significantly with Suffix Type, $\underline{F}(1,22) = 5.53$, $\underline{MS}_e = .965$, $\underline{p} = .0281$, owing to the written recall condition resulting in a greater number of target errors under the F suffix than under the P suffix, while the spoken condition yielded virtually the same number of target errors under both F and P suffixes. In addition, a significant interaction of Age X Target Letter Error was obtained, $\underline{F}(1,22) = 7.42$, $\underline{MS}_e = .340$, $\underline{p} = .0124$. This was due to the fact that although both groups had more S than R errors, the difference between the two was greater for the elderly than for the young.

Finally, a significant Age X Recall Method X Suffix Type interaction, $\underline{F}(1,22) = 4.86$, $\underline{MS}_e = .965$, $\underline{p} = .0383$ was due to the fact that for young subjects in the written recall condition, more target errors of both types occurred under the F than under the P suffix, while in the spoken recall condition, there was an equal amount of target errors under both suffixes. For elderly subjects, there was little difference in target errors under any of the conditions.

Thus, although the F suffix appears to have been less troublesome in this auditory-visual condition, target errors under the F suffix were dominant, and S errors were more frequent than R errors, irrespective of Suffix Type.

Intrusion Errors. Intrusion errors are shown in Table 11, and suffix intrusions for the suffix condition only (as no suffix intrusions crossed over into the control conditions) are displayed in Table 12.
Note the greater overall number of intrusions for the elderly in every category.

A 2 (Age) X 2 (Suffix) X 2 (Recall Method) ANOVA yielded significant main effects of Age, $F(1,22) = 4.87$, $MS_e = 8.50$, $p = .0381$ and Suffix, $F(1,22) = 8.80$, $MS_e = .995$, $p = .0071$. These were due, respectively, to the greater number of intrusion errors on the part of elderly as compared to young subjects, and to the greater number of intrusions in the suffix as compared to the control condition.

A significant Age X Suffix Interaction, $F(1,22) = 4.62$, $MS_e = .995$, $p = .0429$ was due primarily to the greater increase in intrusion errors under the suffix shown by the elderly as compared to the young subjects.

The actual number of suffix-for-target-substitutions was tallied for the young and elderly; only one substitution error was made by the young, and that was an "F" for "S" error in the spoken recall condition. Interestingly, the elderly subjects also made only one suffix-for-target substitution, "P" for "R", also in the spoken condition, and

Table 11

Intrusion Errors for the Young and Elderly, and the Proportion of Subjects Generating Them in the Auditory - Visual Condition of Experiment 2.

	Intrusions	Proportion with errors
Young		
Written		
Control Condition	2	.17
Suffix Condition	5	.33
Spoken		
Control Condition	0	0
Suffix Condition	1	.08
Elderly		
Written		
Control Condition	17	.42
Suffix Condition	24	.67
Spoken		
Control Condition	7	.25
Suffix Condition	24	.58

Table 12

Suffix Intrusions made by Young and Elderly Subjects in the Suffix Conditions of the Auditory - Visual Modality of Experiment 2.

Young	Intrusions	As Proport.of Total Intrusions in Suff.Cond.[a]
Written	2	.60
Spoken Recall	1	1.00
Elderly		
Written	14	.58
Spoken Recall	19	.79

[a]Proportion of the total number of intrusions, i.e. extra - list as well as suffix, in the suffix conditions.

unlike the pure auditory condition in which there were a number of "F" for "S" substitutions on the part of this age group. Again, the extra list intrusions had a phonological/alphabetic order basis.

It would seem then that the "P" suffix not only resulted in a slightly poorer overall performance for the elderly, but also in a greater number of intrusions.

The young, on the other hand, again showed that although their performance was differentially affected by suffix types more than that of the elderly, the suffixes did not cause as great an increase in intrusion errors as they did for the elderly, nor was there a tendency on the part of the young to make more intrusions under one type of suffix.

The Visual Condition

Method

Subjects. Twelve young (nine female, three male) and twelve elderly (seven female, five male) Hunter subjects voluntarily participated. The age range of the young was 19 to 26 years, with a mean of 22.33 years, and the age range of elderly subjects was 60 to 82 years, with a mean of 72 years.

Again, elderly subjects were well educated with a mean of 17.0 years of education. The mean mini-mental score was 29.92, and their mean letter span was 6.4 letters.

Young subjects were primarily undergraduate students at the College, with a mean mini-mental score of 29.99 and a mean letter span of 6.33 letters.

No subjects were on medications that would impair performance and none reported difficulty in seeing the stimuli.

Stimuli and Experimental Design. The same stimuli and design used in the auditory and auditory-visual portion were employed.

Apparatus and Procedure. These were the same as in the auditory-visual, with the exception that subjects were instructed to read the letters silently as they appeared on the screen. They were also cautioned against mouthing the letters and were told to be sure to read the "recall signal" before they began to respond.

Results

Control and Suffix data for all subjects are displayed in Table 13.

A 2 (Age) X 2 (Recall Method) X 2 (Position) ANOVA was performed on the control data, yielding main effects of Age, $F(1,22) = 29.72$, $MS_e = 2.00$, $p < .00001$, and Position, $F(6,132) = 38.27$, $MS_e = 1.76$, $p < .00001$. These were due to the superior performance of young subjects as compared to that of the elderly and superior performance of all subjects at the early list positions in comparison to the mid and later positions.

A significant Age X Position interaction $F(6,132) = 2.95$, $MS_e = 1.76$, $p = .0099$ was due to the increasingly

Table 13

Mean Number of Correct Responses as a Function of Age, Suffix, Modality and Position in the Visual Modality of Experiment 2

	Serial Position							
	1	2	3	4	5	6	7	M
Young								
Written								
Control	7.75	6.83	6.25	6.00	5.42	5.50	6.08*	6.26
Suffix	7.58	6.67	6.67	5.75	5.67	5.17	5.17	6.10
Spoken								
Control	7.75	7.00	6.50	5.92*	4.83	5.42*	5.42	6.12
Suffix	7.58	6.75	6.00	5.17	5.33	4.75	5.17	5.82
Elderly								
Written								
Control	6.33*	5.08	4.00	3.50*	2.75	2.75	2.50*	3.85
Suffix	5.58	4.83	3.92	2.92	2.58	2.33	1.92	3.44
Spoken								
Control	6.17*	5.33	4.42	3.33	2.75*	2.25*	2.50*	3.75
Suffix	5.25	4.83	3.92	2.92	1.75	1.42	1.83	3.13

Note. * Denotes a significant Dunnet test; C-E = .56.

inferior performance of the elderly with respect to that of the young at list positions two through seven. It is interesting to note that in this visual condition, the mean letter span of the elderly was slightly higher than that of the young.

Recency. Significant recency was found for the young in the written ($t[11] = -1.87$, $p < .05$) but not in the spoken ($t[11] = 0$, $p = 0$) recall condition. The elderly showed no significant recency in either the written ($t[11] = .477$, $p < .05$) or spoken ($t[11] = -.82$) condition.

Recall Method. No significant differences with respect to mode of recall were found for either age group.

Suffix Condition. A 2 (Age) X 2 (Suffix) X 2 (Recall Method) X 7 (Position) ANOVA was performed on the suffix data, yielding significant main effects of Age, $F(1,22) = 31.78$, $MS_e = 34.32$, $p < .00001$; Suffix, $F(1,22) = 5.44$, $MS_e = 5.52$, $p = .0290$; and Position, $F(6,132) = 61.53$, $MS_e = 2.12$, $p < .00001$. These were attributed to the superior performance of young over elderly, the detrimental effect of the suffix, and inferior performance at later positions under the suffix, respectively.

Only the Age X Position interaction was significant, $F(6,132) = 3.30$, $MS_e = 2.12$, $p = .0046$), and was once again due to the fact that as list length increases, the elderly performance becomes increasingly poor with respect to that of the young.

Interestingly, although the relevant age and suffix interactions were not significant in the ANOVA, the suffix effects noted in Table 13 are more extensive for the elderly than for the young in terms of the number of positions affected in both recall modes. While visual suffix effects are less often seen, (see, for example, Crowder & Morton, 1969; Manning & Schreier, 1988) they have, in fact, been reported (Hitch, 1975) and in experiment I above. It is also interesting to note that performance at Position 1, which has been notably less affected in all of the above experiments, has been disrupted in both written and spoken recall for elderly subjects alone in this visual suffix condition. In one sense, this may be considered an age related, modality specific deficit.

Recency under the Suffix. No significant recency was observed in either the written or spoken condition for the young, $t(11) = -1.00$, and $t(11) = 0$, or for the elderly, $t(11) = 1.04$, and $t(11) = -1.10$, respectively.

Suffix Type. A 2 (Age) X 2 (Recall) X 2 (Suffix Type) X 7 (Position) ANOVA was performed on the data summarized in Table 14, and, as above, only the findings related to Suffix Type will be discussed.

In this condition, there was no significant main effect of Suffix Type. However, Suffix Type did interact significantly with Recall Method, $F(1,22) = 5.25$, $MS_e = 1.35$, $p = .0319$). F suffix performance was just slightly

Table 14

Mean Number of Items Correctly Recalled as a Function of Age, Recall Method, and Suffix Type Position in the Visual Condition.

	Serial Position							
	1	2	3	4	5	6	7	M
Young								
Written								
Suffix F	3.83	3.50	3.58	3.08	3.08	2.58	2.50	3.17
Suffix P	3.75	3.17	3.08	2.58	2.83	2.67	2.67	2.97
Spoken								
Suffix F	3.67	3.33	3.00	2.50	2.58	2.33	2.50	2.85
Suffix P	4.00	3.33	2.83	3.00	2.75	2.33	2.58	2.97
Elderly								
Written								
Suffix F	3.00	2.33	1.58	1.50	1.42	1.33	0.83	1.71
Suffix P	2.83	2.00	2.08	1.50	1.17	1.00	1.08	1.67
Spoken								
Suffix F	2.25*	2.25	1.42	1.17*	0.75	0.75	0.67	1.32
Suffix P	2.92	2.58	2.25	1.83	0.83	0.92	1.08	1.77

Note. * Denotes significant Dunnett test; C - E = .58

better than P performance in the written condition, but worse than P in the spoken condition.

Since there was no main effect of Suffix Type, or no interaction with Age, target errors were not analyzed.

Intrusion Errors. Finally, intrusion errors are displayed in Table 15.

Note that in this modality, elderly subjects show the fewest intrusions as compared to the other two modalities.

A 2 (Age) X 2 (Suffix) X 2 (Recall Method) ANOVA was performed on these data, yielding no significant main effects or interactions. For both groups there were no suffix-for-target substitutions; the few extra list intrusions were phonological/alphabetic order based.

However, Table 16 shows that for elderly subjects, of the intrusions made in the suffix conditions, the majority were intrusions of the suffix as opposed to extra-list intrusions, in both spoken and written recall.
The young, however, had no intrusions of the suffix in either Recall condition.

Summary and Discussion

Although young performance was superior to elderly in all three modalities, standard serial position, bow shaped curves were obtained in the control conditions for both age groups.

Recency occurred in young and elderly performance in both the auditory and auditory-visual conditions, and was

Table 15

Intrusion Errors for the Young and Elderly, and the Proportion of Subjects Generating Them in the Visual Condition of Experiment 2.

	Intrusions	Proportion with errors
Young		
Written		
Control Condition	4	.17
Suffix Condition	3	.17
Spoken		
Control Condition	3	.25
Suffix Condition	1	.08
Elderly		
Written		
Control Condition	8	.25
Suffix Condition	7	.25
Spoken		
Control Condition	1	.08
Suffix Condition	7	.42

Table 16

Suffix Intrusions made by Young and Elderly Subjects in the Suffix Conditions of the Visual Modality of Experiment 2.

Young	Intrusions	As Proport.of Total Intrusions in Suff.Cond.[a]
Written	0	0
Spoken Recall	0	0
Elderly		
Written	7	1.00
Spoken Recall	6	.86

[a]Proportion of the total number of intrusions, i.e. extra - list as well as suffix, in the suffix conditions.

marginally present for the young in the purely visual condition.

The pervasive interaction of Age and Serial Position, present in all three modalities of Experiment 2 as well as in Experiment 1, was, in all cases, due to the age difference in performance becoming larger at later list positions. Although in three of the studies the young letter spans were longer than those of the elderly, the differences were not significant, and in the fourth case, the elderly letter span was slightly longer than that of the young. Clearly other factors, such as the inability to sustain this span length, may play a part in the elderly's poorer end of sequence performance.

The failure of recall mode to have a significant effect in any of the three modalities of Experiment 2 control conditions was in part contradictory of Experiment 1, in which written recall was superior in the visual modality. The failure to achieve comparable significance in the visual condition of Experiment 2 may be due partially to the smaller subject number, as the trend for superior written recall was clearly evident in the visual, but not the auditory or auditory-visual modalities.

With the introduction of the suffix, age differences in performance were exacerbated, especially in the auditory condition of Experiment 2, in which the elderly experienced not only more widespread, but also substantially larger suffix effects at the later list positions than did the young. As was predicted, the elderly were more susceptible to the auditory interference than were the young. In terms of number of positions affected, the elderly had more positions adversely affected than the young in all of the modalities; the least number of positions affected for both groups was in the visual mode, where the elderly still had about twice as many positions negatively affected as the young.

Spoken recall under the suffix seemed to present a greater problem for the elderly than for the young under the auditory-visual condition, as was evidenced by significant suffix effects at every position. This can be contrasted with the less pervasive effects in the young performance, or indeed in their own performance, in the written condition. Perhaps the reading aloud of the stimuli as they appeared on the screen not only prevented rehearsal, but caused some sort of feedback type interference between the stimulus production and the oral recall. This, coupled with the interference of the suffix itself, may have resulted in the list wide effects.

A comparison of the two experiments suggests that elderly performance in Experiment 2 suffered more under the suffix than in Experiment 1. This, coupled with the increase in positions affected by the suffix in the visual modality of Experiment 2, seen in both age groups, may have been due to the different suffices employed in the two studies. In the first study, the suffixes "V" and "Y" were neither auditorily nor visually similar to the letters of the stimulus set, as were F and P. Additionally, they are letters which are both located at the end of the alphabet, and may therefore have been perceived as somewhat distinct from the set, in contrast with letters F and P, which are close to the middle.

While it is not the focus of this paper to theorize concerning the much contested basis for the suffix effect, it seems that these visual suffix effects may support the final item distinctiveness theory (Manning and Robinson, 1989; Routh & Frosdick, 1978; Salter, 1975) of suffix effects, which generally holds that if the final item of a to-be-remembered set does not remain distinct from the suffix, then regardless of the modality, suffix effects will emerge. Of course, these data are also supportive of a theory of suffix effects that ascribe them to a failure of attentional processes (Kahneman, 1973), namely the failure to make the suffix less salient than the other members or to group it separately, thereby resulting in the suffix effect. However, in an experimental situation in which visual stimuli are presented serially, what exactly are the consequences or specific effects of including the suffix in the set? It is unlikely that a visual sensory store is being overwritten with this design. The answer lies perhaps in the suffix exceeding a span limit, or possibly in its acting "auditory" as a consequence of articulatory coding, thereby displacing the last item or two from an auditory or articulatory store. Whatever the mechanism, the key to avoiding the effect is to exclude the suffix from working memory, to bracket it. This ability seems to be lacking in elderly subjects in these studies.

The presence of visual suffix effects, seen to a greater extent in the elderly than in the young in both Experiment 1 and 2, may have been due to the elderly having recoded or sub-vocalized the suffix into an auditory or phonological form, resulting in mild interference. The young, on the other hand, were able to exclude the suffix from the articulatory coding of the visually presented letter set, to treat it as a meaningless mark, devoid of any sound association, much as the dash (-) in the control condition was treated. Moreover, the visual condition presents the least opportunity for including the suffix in the list, as one is not forced to hear the suffix and is potentially able to omit it in the manner just mentioned.

Whether or not the suffix in the visual modality truly exerts phonologically based interference may be less important than the fact that one group was better able to exclude the suffix in the first place, and that seems to be the basis for the age differences in performance under the suffix condition in both modalities.

Hitch (1975) succeeded in producing a small terminal visual suffix effect for serially recalled letters, and studied the role of attention in suffix effects of both modalities by creating a "training" condition, wherein irrelevant letters, identical to the suffix, were interpolated with the list items. His subjects learned to ignore the suffix and thereby reduce its effects, in the visual condition only. Interestingly, the visual suffix effect he demonstrated was done so in an oral response mode. Recall that the visual suffix effects in Experiment 1 were present for elderly, and not young, and that in Experiment 2, in the visual condition, these suffix effects were more widespread for the elderly, especially in the spoken recall condition. As noted above, Baddeley and Hull (1979) and others propose that preterminal suffix effects exist and are attentionally based. In the current studies, the elderly, in general, showed preterminal suffix effects to a greater extent than did the young, in terms of a greater number of preterminal positions having been negatively affected.

In both the auditory and auditory-visual modalities in Experiment 2, young subjects were, in general, more sensitive to the difference in suffix types than the elderly, performance differences between the two types having been larger than those of the elderly. This again suggests that the young may be better able to selectively filter than the elderly, and is reminiscent of the findings of Mc Dowd and Filion (1991), discussed in the introductory remarks. Again, these authors showed that elderly were unable to block out irrelevant stimuli, and their SCOR's (skin conductance orienting responses) were virtually identical for attend and ignore conditions. The young, however, showed a difference between those two conditions.

Target error analyses did not fully clarify the differential performance under the F and P suffices. However, in the auditory modality, the P suffix did prove to be less difficult, especially for the young, and the associated target letter errors (R) were less frequent, again, primarily for the young. This suggests that the manipulation was somewhat successful: F (auditorily confusable with S) was the more difficult, and S errors were the more frequent, in the purely auditory condition. The fact that S errors dominated even under the P suffix may reflect the fact that the different suffices were not blocked within a list, and effects of the F suffix could have carried over to a list suffixed with P. A better design for the investigation of these suffix and target letter variables would include a blocked presentation. Alternatively, and as noted above, S errors may have been more dominant because of the letter S beginning with the same vowel sound as the list letters L and M.

In the auditory visual condition, the overall main adverse effect of the F suffix was no longer present;

instead other variables such as Age and Suffix determined whether F or P had the greater deleterious effect. It is somewhat unclear as to the meaning of young subjects having slightly more difficulty with the F than the P suffix in the written recall condition, while elderly subjects had slightly more difficulty with P in both spoken and written recall conditions. It is possible though, that the introduction of the visual dimension presented a problem for the elderly in terms of the visually similar suffix P and target letter R.

The target error analysis for this condition showed the continued dominance of S over R errors, but the fact that there was a greater equivalence with regard to the number of target errors for each suffix may also be indicative of the increasingly negative influence of P, and/or the decreasing negative influence of F with the visual augmentation of the stimuli. Note also that again the young seemed to be more differentially sensitive to suffix types than were the elderly.

The visual condition seemed the least vulnerable to Suffix Type manipulation, as it was for the suffix manipulation itself. However, the elderly did have more trouble with the F suffix than with the P in the spoken condition, in which they exhibited some suffix effects. This need not have been so; both suffixes could have diminished performance equally. It is tempting to speculate that for this group, the oral recall of the stimuli was more vulnerable to the auditory confusability provided by the F suffix.

As in Experiment 1, the extra list intrusions, more numerous for elderly subjects than for the young, were phonological/alphabetic order based, and again extend the possibility that the elderly are more susceptible to internally generated, phonological, task competitive noise. Interestingly, the smallest number of intrusions made by elderly subjects was in the visual condition. However, those few that were made were suffix intrusions, indicating that the elderly still had difficulty blocking the suffix, and suggesting that phonologically based, task competitive "noise" may be a seperate issue from failing to block the suffix. The fact that elderly subjects in the auditory-visual spoken recall condition made more intrusions than those in the pure auditory spoken recall and visual spoken recall conditions, may also reflect the difficulty the elderly subjects may have had when rehearsal or review was eliminated. After all, the auditory-visual spoken recall condition, still subject to phonological interference, offered the least opportunity for rehearsal of the list letters. Moreover, in the pure auditory and visual conditions, written intrusions were far greater than spoken, suggesting that the intrusions themselves were not solely the function of any confusion or external "noise" merely generated by answering aloud.

As was noted above, young and elderly subjects seemed to have come to the experimental situation "primed" with regard to the alphabet set, as many of the extra-list intrusions were directly related to the order of the letters in the alphabet sequence (e.g., "K" for a letter when preceded by "J", or followed by "L"; "N" following "M"; "P" preceding "Q"). The failure to maintain a focus of attention over a number of trials may also be the basis for the greater number of elderly extra-list intrusion errors, and in fact, although no formal analysis was done, an inspection of intrusion errors showed that they tended to occur mainly after position four.

Despite the differential performance with respect to suffix type, the young showed no difference in the amount or type of intrusions as related to suffixes, or types of suffixes, while the elderly clearly did. In every modality, the elderly clearly surpassed the young in the number of intrusions. Only the elderly had a number of suffix-for-target substitutions ("F" for "S") in the auditory modality, whereas they were equally and negatively affected in terms of recall by both suffixes. On the other hand,the young showed inferior "F" performance in this mode with respect to "P" performance, yet no substitutions were made.

In summary, the overall picture of age related differences in the suffix paradigm as suggested by these studies, seems to be one of an elderly population, who despite its being well educated, vital, and not differing significantly in terms of letter span from the young, is consistently and reliably less proficient at end of sequence recall, and more prone to auditory interference and phonological based intrusion errors than young. As stated above, it is proposed that these differences are attributable to a greater susceptibility to task extraneous noise, be it externally or internally generated; the number and nature of the intrusions gives credence to this notion. In addition, over repeated measures of letter span, one might see the span decrease or at least fluctuate as a failure to selectively attend to the task at hand becomes more likely. With the introduction of the suffix, these age differences are exacerbated, especially when auditory presentation is involved.

What, if any, are the practical applications of these findings? For one, memory improvement techniques may emphasize assisting elderly subjects to better focus on the task at hand rather than on employing mnemonic aids. In fact, many of the elderly subjects reported the use of such techniques as association of the list letters with names, places, etc., while young subjects rarely employed this strategy. It seems that such mnemonic aids have become popularly associated with memory improvement in the elderly. Perhaps drug therapies with agents known to improve attentional capacities such as those used in the treatment of Attention Deficit Disorder (a symptom of which is poor short term recall) would be considered more of an option.

Experiment 1 suggested that elderly may suffer when responses to visual material are recoded into oral form. Perhaps modifying assessment techniques to disallow cross modal responding would result in better evaluation. In addition, studies such as those reported here should manifest a greater awareness of the possibility of compensatory mechanisms that have been naturally adopted by elderly subjects. Had the standard answer sheets been used, with all the previously recorded sequences available for review, the intrusion errors might have been absent, as they were in previous studies which used the standard answer sheets.

IMMEDIATE RECALL OF CONFUSABLE AND NON-CONFUSABLE STIMULI

Experiment 3

As noted in the introductory remarks, research suggests that the elderly may be deficient in visual coding and therefore more dependent on auditory or phonological processes in admitting information to short term memory (McGhie, Chapman & Lawson, 1965; Arenberg, 1965; Manning & Greenhut, 1991). Articulatory processes which allow access of visual material to the phonological store (Baddeley & Hitch, 1974) may also become increasingly important with age.

The study reported below attempted to eliminate or reduce articulatory processes such as sub-vocalization, which are used in memorizing sequentially presented visual stimuli. Moreover, half of these stimuli were acoustically similar, and were therefore less well recalled than distinctive letters, despite their visual presentation (Conrad, 1964) Articulatory suppression has been shown to eliminate this confusability effect (see, for example, Salame and Baddeley, 1982; Vallar & Baddeley, 1984; Hitch, Wodin & Baker, 1989).

Confusability should cause more of a problem for older subjects, since they may possibly depend more on articulatory processes for access to short term memory than do the young, and appear to be more sensitive to phonologically based "noise" as evidenced by the intrusions in the previous studies. It also seems likely that when forced to abandon articulatory processes used in memorizing the distinctive letters, the elderly recall will be more negatively affected than that of the young. In addition, the confusability effect should be reduced for both groups under articulatory suppression.

Method

Subjects

Twelve young (eight female, four male) and elderly (seven female, five male) Hunter College students participated on a voluntary basis. The age range for young subjects was 19 to 28 years, with a mean age of 23.8 years. Elderly subjects ranged in age from 60 to 83 years with a mean of 69.83 years.

Elderly subjects were very well educated with a mean of 16.5 years of education. The mean mini-mental score was 29.67, and their mean letter span was 6.0 letters.

Young subjects were primarily junior and senior undergraduate students at the College, with a mean mini-mental score of 29.67 and a mean letter span of 6.08 letters.

No subjects were on medications that would impair performance and none reported difficulty in seeing the stimuli.

Stimuli and Experimental Design

There were four conditions: Non-suppression non-confusable, non-suppression confusable, suppression non-confusable and suppression confusable. All subjects received all conditions. Three separate fully balanced latin squares were used to assign condition and list order for each subject. Four lists of distinctive and confusable stimuli were employed, each list consisting of eight six letter sequences which had been randomly constructed and assigned to a particular list. All lists of each type contained different sequences of the same stimuli, and each subject received every list.

The non-confusable and confusable sets consisted of the uppercase letters J,Q,R,L,M,S and B,C,D,P,T,V, respectively (see Manning, 1977 for rating data).

Answer booklets consisting of eight pages, each having six lines for subjects to record their six letter responses, were employed.

Apparatus and Procedure

The letters were presented on a Fountain microcomputer with an 8088 microprocessor and a clock speed of 8mhz. Letters were presented sequentially in the center of the amber monitor at a rate of 1 per second (.5 second on, .5 second off), and there was twenty second interval between sequences during which the subjects recorded their answers. A beep of .5 second duration signalled that the next list was about to begin; 2.5 seconds intervened between the warning signal and the subsequent list.

In the non-suppression condition, subjects were instructed to read the letters silently as they appeared on the screen, and were cautioned not to mouth the letters. In the suppression condition, they were required to begin saying the word "the" (pronounced with a short e sound) as soon as they heard the beep, and to continue doing so until they had finished writing their answers. Subjects were advised not to try and synchronize the word "the" with the letters appearing on the screen, or to say the word in a loud voice. All that was required was that the word be audible to the experimenter. In this way it became a rote task rather quickly.

Recall was to be in strict serial order and no backtracking was allowed. Subjects were encouraged to guess if they did not recall a letter.

Three practice sequences were given before each condition, during which time the experimenter verified that the subjects had no problem seeing the stimuli and that they were proceeding properly. At all times during the study the experimenter sat close by and observed the subjects to be sure all directions were followed.

Results

Means for all conditions for both age groups are displayed in Table 17.

Confusability

A 2 (Age) X 2 (Confusability) X 6 (Position) ANOVA was performed on the control data (without supression), yielding significant main effects of Confusability, $\underline{F}(1,22) = 45.93$, $\underline{MS}_e = 4.32$, $\underline{p} < .00001$ and Position, $\underline{F}\ (5,110) = 53.73$, $\underline{MS}_e = 1.95$, $\underline{p} < .00001$. These were due to superior performance in the non-confusable condition and to better performance at early list positions as compared to the later positions. A marginally significant main effect of Age was also attained, $\underline{F}(1,22) = 3.35$, $\underline{MS}_e = 17.24$, $\underline{p} = .0801$, and can be attributed to the superior performance of the young as compared to the elderly.

A significant Confusability X Position interaction,

Table 17

Mean Number of Correct Responses as a Function of Age, Supression, Confusability and Position in Experiment 3.

	Serial Position						
	1	2	3	4	5	6	M
Young							
Nonsuppression							
Dissimilar	7.75	7.17	6.75*	6.17*	6.17*	6.92*	6.82
Confusable	7.25	6.58	5.58	4.08	4.17	4.50	5.36
Suppression							
Dissimilar	7.08	5.58	5.08*	4.42*	3.58	4.58*	5.05
Confusable	6.75	5.42	4.17	2.83	3.00	3.33	4.26
Elderly							
Nonsuppression							
Dissimilar	7.50*	7.17*	6.08*	5.25*	5.08*	5.67*	6.13
Confusable	6.50	5.17	4.25	3.33	3.00	3.33	4.26
Suppression							
Dissimilar	5.50	4.33	3.83	2.33	2.08	2.75	3.47
Confusable	5.83	4.33	3.92	2.53	2.00	2.08	3.44

Note. * Denotes a significant Dunnet test; C-E = .90

$\underline{F}(5,110) = 3.04$, $\underline{MS}_e = 1.39$) was the result of the confusability exerting a greater negative effect at the end as compared to the beginning of the list.

Recency

Recency, as defined as the superior performance at the penultimate as compared with the last position, was not present for young subjects in either the non-confusable list, $\underline{t}$ (11) = -1.75, $\underline{p} > .05$, or in the confusable list $\underline{t}(11) = -1.17$, $\underline{p} > .05$. Elderly subjects also failed to show recency in either the non-confusable, $\underline{t}(11) = -1.16$, $\underline{p} > .05$, or confusable condition, $\underline{t}$[11) = -.77, $\underline{p} > .05$. These results are expected in light of the visual presentation modality.

Confusability and Articulatory Suppression

A 2 (Age) X 2 (Suppression) X 2 (Confusability) X 6 (Position) ANOVA yielded significant main effects of Age, $\underline{F}(1,22) = 6.37$, $\underline{Ms}_e = 24.88$, $\underline{p} = .0194$); Suppression, $\underline{F}$([1,22) = 42.72, $\underline{MS}_e = 8.45$, $\underline{p} < .00001$); Confusability, $\underline{F}(1,22) = 27.86$, $\underline{Ms}_e = 5.53$, $\underline{p} < .00001$); and Position, $\underline{F}(5,110) = 87.54$, $\underline{MS}_e = 1.62$, $\underline{p} < .00001$). These were due, respectively, to the overall superior performance of the young, the superior recall in the non-suppression vs. the suppression condition, the superior performance in the non-confusable condition, and better recall at earlier rather than later positions.

A significant interaction of Suppression X

Confusability $\underline{F}(1,22) = 18.45$, $\underline{MS}_e = 3.05$, $\underline{p} = .0003$ is attributed to suppression having exerted more of a negative effect in the non-confusable than in the confusable condition.

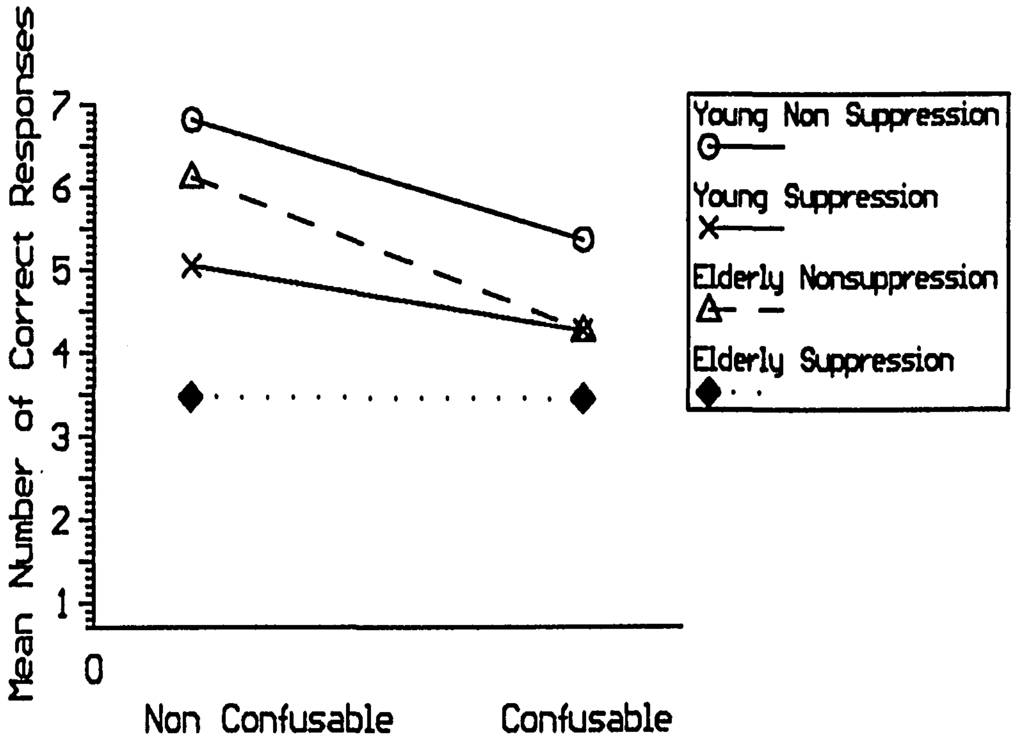
A Confusability X Position interaction was also significant, $\underline{F}(5,110) = 4.40$, $\underline{MS}_e = 1.16$, $\underline{p} = .0011$, and was due to confusability having had its greatest negative effect on recall at the final list positions.

Finally, an Age X Suppression X Confusability interaction, shown in Figure 7, was marginally significant, $\underline{F}(1,22) = 4.02$, $\underline{MS}_e = 3.05$, $\underline{p} = .0575$.

Young subjects showed a somewhat greater drop in recall between the two suppression conditions in the non-confusable condition than they did in the confusable condition, again suggesting that the prevention of articulatory rehearsal was more detrimental to recall of the acoustically dissimilar than to the similar letters.

As can be seen in Figure 7, elderly recall showed a similar but much larger drop between the non-suppression and suppression conditions for the acoustically dissimilar than for the similar letters, and the difference between suppression and non-suppression conditions for the confusable letters was smaller for the elderly than for the young. Thus, suppressing articulation of non-confusable letters was far more detrimental for the elderly than for the young. Also, older subjects showed no difference in

Figure 7. The interaction of Age, Suppression, and Confusability in Experiment 3.


Mean Number of Correct Responses
7
6
5
4
3
2
1
0
Non Confusable
Confusable
Young Non Suppression
Young Suppression
Elderly Nonsuppression
Elderly Suppression

recall of confusable and non-confusable letters in the suppression condition, while young showed a decline. Thus, suppression seems to have equalized performance in the two confusability conditions for elderly, but not for young subjects.

For each subject in each age group, the difference between suppression and non-suppression performance in both the confusable and the non-confusable conditions was obtained. Independent t tests were performed, and showed that the decline in recall between suppression and non-suppression performance in the non-confusable condition was significantly greater for the elderly subjects than for the young, $t(22) =- 1.81$, $p <.05$. These findings are in agreement with the above interaction: elderly subjects found the suppression of articulation to be quite disruptive in the recall of the non-confusable letters, while the young found it to be less so.

Recency under Suppression

The young showed significant recency $t(11) = -3.32$, $p < .01$) under suppression for the non-confusable lists but not for the confusable, $t(11) = -.77$, $p > .05$. No significant recency was shown under suppression by elderly subjects in either the non-confusable or the confusable letter condition, $t(11) = -1.54$, $p > .05$, and $t(11) = -.28$, respectively. Hence, for the young, articulatory suppression in the non-confusable condition seems to have strengthened recency into this visual presentation. The less frequently seen visual recency may be understood in terms of articulatory processes, and one would expect a condition which reduces or eliminates such processes to reduce or eliminate recency. Instead, the opposite situation seems to have obtained here: recency that was not significant without suppression became significant with it, but only for young subjects.

Intrusion Errors

Intrusion errors were tabulated and are presented in Table 18.

An intrusion was characterized as either an extra list intrusion, meaning that it was not contained in either the dissimilar or confusable list, or as a previous list intrusion, having occurred in a previously presented list. Of course, intrusions that could be deemed" previous list" were not characterized as such if they occurred in the first condition of participation.

A 2 (Age) X 2 (Suppression) X 2 (Confusability) ANOVA was performed, yielding significant main effects of Age, $F(1,22) = 5.20$, $MS_e = 3.37$, $p = .0327$ and Suppression, $F(1,22) = 5.07$, $MS_e = 1.73$, $p = .0346$. These were due to the greater number of intrusions made by elderly as compared to young subjects, and to the greater number of intrusions in the suppression rather than the non-suppression condition.

A significant interaction of Age X Confusability was

Table 18

Number of Intrusion Errors for the Young and Elderly, and the Proportion of Subjects Generating Them in Experiment 3.

	Intrusions	Proportion with errors
Young		
Nonsupression		
Dissimilar	0	0
Confusable letters	7	.33
Suppression		
Dissimilar	2	.17
Confusable letters	9	.25
Elderly		
Nonsuppression		
Dissimilar letters	11	.50
Confusable letters	5	.42
Suppression		
Dissimilar letters	35	.66
Confusable	9	.50

obtained, $F(1,22) = 7.31$, $MS_e = 2.64$, $p = .0130$, and can be attributed to the elderly having a far greater number of intrusions than the young in the dissimilar condition, while this difference was smaller in the confusable condition.

A marginally significant Age X Suppression interaction, $F(1,22) = 3.19$, $MS_e = 5.51$, $p = .0878$ indicated that the elderly made more intrusion errors in the suppression condition as compared to the non-suppression condition than did the young.

Extra - list intrusions were, for the most part, phonological/alphabetic order based. Often the letter "K" replaced "Q," or the letter "K" replaced a list letter which was preceded by "J" or followed "L" in the series; the letter "N" was substituted for "M", or for a list letter which followed "M" in the series; the letter "U" was placed between "T" and "V", etc.

Discussion

Although the overall magnitude of the confusability effect was not greater for the young than for the elderly, the latter group showed a greater susceptibility than the former to this manipulation in terms of all positions having been negatively affected. It would seem then that for the elderly, rehearsal of the confusable letters was not as effective as it was for the distinctive letters in producing the usual superior performance at the first one or two positions, as is typically seen in the serial position curve. This, coupled with the fact that suppression of articulation had a resounding detrimental effect on recall of non-confusable letters, suggests that older subjects relied quite heavily on sub-vocalization in this task.

On the other hand, the young, whose performance at the first two positions of non-suppressed recall of confusable letters remained intact, and whose non-confusable recall was not as detrimentally affected under suppression, may have been less reliant on an articulatory process.

While non-suppression performance remained superior for both groups, suppression reduced the difference between confusable and non-confusable performance, especially for the elderly. This may be indicative of some articulatory process lingering in the young, even under suppression, as might the recency that persisted for this group.

The overwhelmingly greater number of intrusions errors in the suppression, non-confusable condition made by elderly subjects corroborates that this was the most difficult of tasks for them. The intrusions themselves may be related to the overall greater internal noise or task competitive interference experienced by elderly subjects (Hasher & Zacks, 1988), as their auditory/alphabet nature suggest. In this study, such interference may have been exposed by the booklet method of recording responses, thereby removing the possibility of reviewing letters from the preceding lists in that condition, as was suggested in Experiments 1 and 2.

Another contributing factor may have been that list types could change after only eight trials. Thus, letters from previous lists may have "lingered", providing a greater amount of background noise or interference for elderly compared to the young subjects.

As far as the suppression condition possibly having caused the age differences by dividing attentional resources between two tasks, it should be noted that the repetition became rote fairly quickly as reported by nearly all the subjects. Baddeley (1986) cites a study by Morris who found that demented, but not normal elderly subjects, suffered a performance deficit in a Peterson paradigm in which articulatory suppression was required in the delay interval. He investigated this possibility of suppression causing a decrement in performance of demented subjects by virtue of its attention siphoning potential by including a condition in which subjects (demented and normal elderly) were required to finger tap instead of suppressing articulation. Only demented patients were found to suffer a decrement in performance, but not of the magnitude seen under suppression.

Moreover, in another study conducted in this laboratory, subjects were required to repeat the word "the" while judging letter pairs on a similarity dimension. Under all conditions, the suppression significantly <u>improved</u> reaction time for elderly, but not for young subjects. This provides evidence against articulatory suppression being disruptive by virtue of simply requiring a considerable amount of attention for its successful execution, thereby significantly competing with the memory task for attention and processing resources.

In summary, these data suggest that elderly are more dependent upon articulatory processes than the young for admitting information to short term memory. Elderly subjects may be less able than the young to access short term memory via a visual channel for sequential information. Anecdotal evidence in this lab also attests to this, wherein elderly subjects waiting to participate in a study frequently have been noted to mouth words as they read a book or newspaper. Moreover, the basis for this reliance on this articulation or sub-vocalization may in part be due to the increasing susceptibility of the elderly to both external and internal task competitive noise; the articulatory processes provide augmentation of the visual signal and an aid to focusing of attention.

Finally, this paradigm presents a simple way to introduce or increase such "noise", and to gauge the degree and duration of its intrusiveness.

SIMILARITY JUDGEMENTS

After methods fashioned by Posner and Mitchell (1967), Dainoff (1970) and Wood (1974), a procedure was designed to investigate possible differences in coding of alphabetic stimuli by young and elderly adults, the premise being that differences in reaction times will reflect differences in cognitive processes involved in the coding of stimuli. As was noted above, evidence suggests that the elderly are deficient in visual coding, and that they are more susceptible to auditory interference than the young. The current studies attempted to compare phonological and visual coding of various stimuli, both between and within age groups.

Posner and colleagues (Posner & Keele, 1967, & Mitchell, 1967) conducted a series of reaction time (RT) studies in which pairs of letters were presented and subjects were required to respond "same" or "different" by pressing corresponding keys as rapidly as possible. Letter pairs were either upper case, lower case, or some combination of the two. Two levels of instruction were employed: one in which subjects were told to classify the stimuli as "same" or "different" according to whether or not they were physically identical, and one in which they were to call the stimuli "same" or "different" on the basis of whether or not the two letters had the same name. It was found that the two types of instruction led to differences in reaction times. With the first type of instructions, there were no differences in "same" (AA or aa) and "different" (Aa, AB, Ab) response times.

The second type resulted in slower reaction times for different stimuli pairs (AB,Ab), presumably because the level of processing required was deeper than was that of processing on the basis of physical characteristics. However, those matches based that could still be made on the basis of physical identity (AA, aa) were faster than those based on name identity (Aa, Ab). That is, it was hypothesized, when processing according to name characteristics, reaction times to different stimuli are slower than to stimuli which are the same.

Posner, Boies, Eichelman and Taylor (1969) extended these findings in a set of studies in which subjects were again required to match letters on the basis of name. However, the inter stimulus interval was varied from 0 to 2 seconds. This resulted in the speed advantage of the name match being lost after two seconds, and the times for "same" and " different" responses were again equal. Presumably the visual information that was immediately available for, and which facilitated the match, decayed over time as the likelihood of name coding increased over time.

Dainoff (1970) used letter pairs that were either aurally confusable or dissimilar and presented in the visual modality, at interstimulus intervals (ISI) ranging from 0 to 2 sec. In addition to replicating Posner et al. (1969), he found that RT's were longer for the confusable letters than for the non-confusable letter pairs, and that this effect increased as the length of the ISI was increased.

Presumably, this indicates that visual coding is being replaced by phonological coding, which is then delayed by the confusable nature of the stimuli.

Wood (1974), in a study of modality specific coding and recoding, presented subjects with pairs of letters that were high in auditory similarity and low in visual similarity (HALV), and low in auditory similarity and high in visual similarity (LAHV). The letters were sequentially presented in both modalities at an ISI of one second. Wood (1974) noted that he was following line of thought put forth by Tversky, that individuals were able to code the same material differently, and that the choice depended upon how the subject expected to use the encoded information. Wood predicted that coding would be modality specific, and therefore, in the auditory mode, HALV reaction times should be lower than those of the LAHV condition, since auditory coding was involved and hampered. In the visual condition, the opposite situation would hold, since the similarity on the visual dimension of the stimulus should now impede the visual coding. This was found to be the case.

In the current studies, subjects were required to make "same" or "different" judgments to pairs of sequentially presented uppercase letters which were:

HAHV - High in auditory and visual similarity.

HALV - High in auditory and low in visual similarity.

LAHV - Low in auditory and high in visual similarity.

LALV - Low in auditory and visual similarity.

SAME - The letter pairs were the same.

Subjects were instructed simply to judge whether or not two letters were the same or different. Two ISI's, .5 and 1 sec. were included because of the findings that auditory coding tended to increase as ISI increased, while the visual code becomes less efficient.

Note that it was not the intention of this study to establish if coding was modality specific, as was Wood's (1974); all stimuli are presented in the visual modality.

Also, the inclusion of HAHV and LALV conditions provides a useful control for gaging coding and its disruption, LALV pairs being totally non-confusable, while HAHV pairs might prove to be more confusing than either LAHV or HALV alone. Thus, strong evidence for either visual or phonological coding requires that two specific comparisons show a significant difference in performance: the aurally similar vs. the visually similar pairs comparison (HALV vs.LAHV), as well as either the aurally similar and dissimilar pairs comparison (HALV vs. LALV), or the visually similar and dissimilar pairs comparison (LAHV vs. LALV). Which of the latter two is necessary depends on whether phonological or visually similar RT's are slower in the first comparison. Weak evidence for coding in a particular dimension would consist of one of the last two comparisons being significant. For example, if one's RT's to the visually similar pairs were significantly slower than one's RT's to the aurally similar pairs, (i.e., visual confusion and visual coding having been inferred) then it would be expected that one's RT's to the visually similar pairs would also be slower than the RT's to the dissimilar pairs.

The significance of only the former comparison (HALV vs. LAHV) would be considered inconclusive. In the absence of any significant above mentioned comparisons, a significant comparison of pairs similar in both dimensions with pairs similar in neither (HAHV vs. LALV) would suggest that both elements of confusability played a part in slowing reaction times.

The inclusion of 12 interspersed SAME stimuli prevented the formation of an automatic "different" response set.

Under this paradigm, there should be a significant overall effect of age, young subjects having the faster reaction times. The shorter ISI should result in faster reaction times for both groups, since residual physical information should assist in the match. Response times to LAHV letter pairs may be slower than to HALV pairs if visual coding is involved and vice versa if auditory coding is used. Confusable pairs in general should result in slower reaction times than non-confusable pairs. Letter pairs high in visual confusion should prove to be more interfering in the .5 second ISI than in the 1 second ISI, as phonological coding becomes more of a factor, and pairs high in aural similarity should be more interfering at the 1 second ISI than at the .5 second ISI. The elderly may be more susceptible to both visual and phonological similarity interference than are the young. Finally, errors should be few and not significantly different for both age groups.

Experiment 4

Method

Subjects

Sixteen young and elderly subjects were recruited from among Hunter College students. The 11 female and 5 male young subjects were between the ages of 20 and 29 with a mean age of 25.25 years. Nine were in their senior year, and seven were graduate students in programs based at the college. The 13 female and 3 male elderly subjects ranged in age from 61 to 78 years, with a mean age of 68.2 years. Three of these had attended college in the past for 1 or 2 years, seven subjects had previously earned a B.A. or B.S. degree, one had earned a Ph.D., one had earned an M.D., one had completed a masters degree and one subject had completed 2 years of graduate school. One did not attend college at all but did graduate from a commercial art school, and one subject's educational background was inadvertently omitted. All but one of the elderly who participated were taking classes at Hunter College for the sake of enjoyment; one was a matriculated student who had recently been awarded the Hunter College writing prize.

All subjects were able to see the stimuli with no difficulty and none were taking medication or had medical problems that could have interfered with cognitive functioning.

Both groups of subjects were administered the Mini-Mental Status test (Folstein, Folstein & McHugh, 1975). The minimum score necessary to participate in the present experiment was 27 out of a possible 30 points, a score well within normal range. The data of those scoring below were eliminated from the study. The mean Mini-Mental score for the elderly was 29.88, for the young, 29.63. No elderly subject scored below 27, while two young subjects were excluded and replaced because of scores below 27.

The study was conducted at Hunter College.

Stimuli and Design

Two lists, consisting of three sets of different upper and lower case letter pairs, in both original and reversed order (24 total) and 12 SAME pairs, were presented visually. The 24 DIFFERENT pairs belonged to the following categories: High auditory, high visual similarity (HAHV), high auditory, low visual similarity (LAHV), low auditory, high visual similarity (LAHV) and low auditory, low visual similarity (LALV). (See Manning, 1977 for rating data.) HAHV letter pairs were MN, PB, BD; HALV pairs were TC, SX, CV; LAHV pairs were RB, NV, TL; LAHV pairs were LX, SR, DM, and SAME pairs were DD, PP, CC, TT, RR, SS, MM, LL, XX, BB, NN, VV.

Two lists of six sets of the above were constructed. Each set consisted of four DIFFERENT pairs and two SAME pairs, for a total of six pairs. Three of the six sets were compiled through random assignment of each element, the only restriction being that stimulus pairs which had a letter in common were not placed in the same set when possible. Three additional sets were formed by reversing the letters of the first three sets, and sets were randomized within lists. Thus, each subject received two lists, each consisting of 12 SAME and 24 DIFFERENT stimuli. The ISI was the same for all pairs in a particular list. Lists (A & B) were linked with intervals resulting in four combinations: A1, A.5, B1, B.5, where 1 refers to a 1 second ISI and .5 to a .5 second ISI. Each subject was randomly assigned to one A and one B condition, and each combination was represented equally among subjects. Practice pairs were WJ, HQ, YY, FG, JK, GG. Note that none of these letters were used in the above pairs. This SAME/DIFFERENT paradigm was part of a larger study which included an immediate recall task, which preceded this one, the results of which were discussed in Experiment 1. All subjects participated in the present research after participating in the immediate recall portion.

Apparatus and Procedure

Stimuli were presented on a Fountain Personal Computer, which has an 8088 microprocessor and a clock speed of 8 mhz and an amber monitor.

The keyboard was covered with a board which allowed only two response keys be exposed. These were the "2" and "3" keys, marked "S" and "D" for the study, located on the number pad portion of the keyboard. Subjects were required to rest the index finger of their preferred hand on a small felt circle which was just below and equidistant from the two response keys. They were instructed to view the first letter of the pair and upon viewing the second letter, to respond as quickly as possible by pressing "S" if the two letters were the same or "D" if they were different, being sure to use only the index finger. This finger was then to be returned to the felt circle to await the next stimulus pair. The first member of the stimulus pair appeared in the center of the screen for 330 milliseconds (ms). The inter stimulus interval was either .5 or 1 second. The second letter then appeared in the center of the screen for 330 ms. Reaction times were recorded in milliseconds and retrieved after the session. Thus, the subjects had no feedback as to their reaction times or correctness throughout the procedure. Each subject received six practice trials, for which the reaction times were not recorded. During these trials the experimenter ascertained if the letters were clearly discernible by the subjects.

In order to ensure that the second stimulus was viewed as long as the first before making the decision, response timing began only after the second letter was visible for 330 ms. However, due to a programming error (discovered after the two experiments reported here were completed) key presses during that 330 ms presentation time were not rejected, as were other premature key presses at various points in the program. It was determined that if the subject pressed the key during this time, the key press was held in the buffer and terminated the timer as soon as it was "released". The response time was recorded as 33 ms. Since in this case the exact response time could not be known, it was decided to remove any subjects who had two of these response times. In this first study, no subject had any of these undeterminable response times. In fact, if subjects adhered to the instructions and kept their index finger on the felt circle in between responses, the problem of pressing during the presentation interval was avoided. Stimulus duration was added onto the recorded response times.

Results

Median RT's were obtained for each subject for each condition and were then averaged. The data for both age groups in all conditions are presented in Table 19.

A 2 (Age) X 4 (Interval) X 5 (Stimulus Type) ANOVA was performed, yielding main effects of Age, $F(1,30) = 11.23$, $MS_e = 330306$, $p = .0022$; Interval, $F(1,30) = 12.03$, $MS_e =$

Table 19

Mean Reaction Times of Judgements to Letter Pairs as a Function of Age, Pair Type, and Interstimulus Interval in Experiment 4.

	HAHV	HALV	LAHV	LALV	SAME
Young					
.5 sec ISI	699.39	685.31	661.15	664.53	662.37
1 sec ISI	724.72	731.90*	766.25*	730.12*	679.75
Elderly					
.5 sec ISI	954.00	867.72	916.59	894.25	862.75
1 sec ISI	985.66	907.47	933.03	908.47	930.00*

Note. * Denotes significant Dunnett test; C - E = 41.

11754.5, p = .0016; and Stimulus Type, $F(4,120) = 3.95$, $MS_\epsilon = 8005.1$, p = .0047. These were due, respectively, to the young having faster RT's than the elderly, to RT's having been faster in the .5 second rather than in the 1 second interval, and to the RT differences among the various Stimulus Types.

A marginally significant Age X Interval X Stimulus Type interaction, $F(4,120) = 2.05$, $MS_\epsilon = 4983.8$, p = .0910, illustrated in Figure 8, suggests that for young subjects, the difference between the .5 second and 1 second ISI is greater than that of the elderly, RT's having been faster for the .5 ISI.

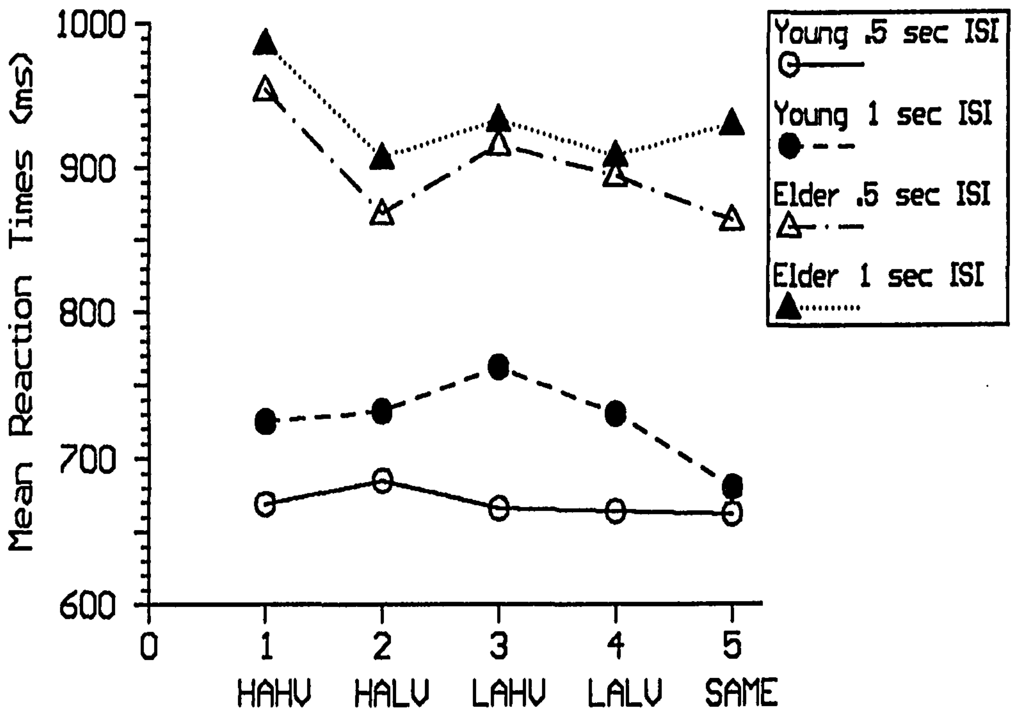
As the tabled Dunnett tests show, the elderly, diverge significantly between these two intervals for SAME pairs only. Thus it seems that they perform with almost equal slowness in both ISI's, while the young are able to respond significantly faster in the .5 second than in the 1 second ISI for HALV, LAHV and LALV stimulus pairs.

Within interval stimulus type comparisons

As described above, planned t tests were made within each ISI condition for performance differences between phonologically similar and dissimilar pairs (HALV vs. LAHV), between visually similar and dissimilar (LAHV vs. LALV) pairs, and between stimulus pairs similar (HAHV) and dissimilar (LALV) on both.

For young subjects in the .5 second ISI, no significant

Figure 8. The interaction of Age, Interval, and Stimulus Type in Experiment 4.



1000
900
800
700
600
Mean Reaction Times (ms)
0
1
2
3
4
5
HAHV
HALV
LAHV
LALV
SAME
Young .5 sec ISI
Young 1 sec ISI
Elder .5 sec ISI
Elder 1 sec ISI

performance differences were found between phonologically similar and visually similar conditions, $t(15) = 1.05$, $p > .05$. Likewise, no significant differences were found when comparing performance for phonologically similar and dissimilar pairs ($t[15] = 1.32$, $p > .05$) or for visually similar and dissimilar pairs $t[15] = .09$, $p > .05$). Even when the stimulus pairs were similar on both dimensions (HAHV), there was no significant difference between this and the dissimilar condition.

For the 1 second interval, these subjects again showed no difference between the phonologically and visually similar conditions, $t(15) = -.99$, $p > .05$. Similarly, none of the other above mentioned comparisons were significant, $t(15) = .047$, $t(15) = .86$, $t(15) = 1.35$, respectively, $p > .05$.

For the elderly, t tests in the .5 second ISI showed that the difference between phonologically similar and visually similar RT's was significant, $t(15) = -2.74$, $p < .001$, RT's in the visually similar condition having been slower than those in the phonologically similar pairs. However, RT's to visually similar pairs were not slower than to dissimilar pairs, $t(15) = 1.19$, $p > .05$. Neither were phonologically similar response times significantly different from those of dissimilar pairs, $t(15) = 1.02$, $p > .05$. However, RT's to stimuli similar in both dimensions were significantly slower than those to dissimilar pairs, t

(15) = 2.36, $p < .05$.

In the 1 second ISI, the difference between phonologically and visually similar pairs is no longer significant, $t(15) = -1.1$, $p > .05$, since in this ISI, the RT's to phonologically similar pairs slowed more than RT's to visually similar pairs, thereby reducing the difference.

Again, phonologically similar were not significantly different from dissimilar RT's, $t(15) = .036$, $p > .05$, and neither were the visually similar different from the dissimilar RT's, $t(15) = 1.43$, $p > .05$. However, as in the .5 second ISI, RT's to pairs similar on both dimensions were slower than those which were dissimilar, $t(15) = 2.41$, $p < .01$.

<u>Error Analyses</u>

Errors were very low in each age group. Misses (responding "different" when given a same pair) and false alarms (FA's--responding "same" when given a different pair) were calculated and expressed as proportions of their total possible occurrence (24 times for different and 12 times for same pairs). If elderly subjects had difficulty resolving the stimuli, then one would expect that they would make significantly more errors than the young.

In the .5 second ISI, young subjects had a total proportion of .17 misses and .21 FA's. In the 1 second ISI, they had a total proportion of .17 miss errors and .17 FA's. Elderly subjects in the .5 second ISI had a total proportion of .083 misses and a total proportion of .17 FA's. In the 1 second ISI they had a total proportion of .333 misses and a total proportion of .17 FA's. Independent *t* tests showed no significant differences between the two age groups in terms of the number of misses (*t*[30] = .59) and FA's, (*t*[30] = .38) in the .5 second condition. Similarly, in the 1 second ISI, there were no significant differences between the groups in the number of misses(*t*[30] = -.745) or FA's (*t*[30] = 0).

Discussion

To briefly reiterate, it was expected that phonological coding would be more of a factor in the processing of the stimulus pairs at the 1 second than at the .5 second ISI; that visually confusable stimuli would yield slower RT's in the shorter ISI, since processing would be more dependent on the physical aspect of the stimulus. Under the longer ISI, it was expected that phonological coding would result in slower RT's to the phonologically similar pairs. Elderly subjects should have been more disturbed by confusable pairs than young, since they are believed to be deficient in visual processing, and to be more susceptible to auditory, or phonological, interference than the young.

For both age groups, the data suggest that phonological coding became more of a factor in the 1 second as compared to the .5 second ISI. That is, response times were generally slower, as would be expected if a shift from making the decision on a physical basis to a name basis had occurred (Posner et al., 1969; Dainoff, 1970).

The finding that young subjects were able to respond faster in the .5 than in the 1 second interval, while elderly RT's in the .5 second ISI were nearly as slow as their 1 second response times, may simply be reflective of the general slowing of reaction time with age, which has been well documented in the literature (See, for example, Plude and Hoyer, 1985).

Regarding the various within-group comparisons performed in order to assess coding, these should have indicated the type of coding employed, as well as any shift in the type of coding in the transition from .5 to 1 second ISI. The fact that young subjects failed to show any significant differences among any of the stimulus pair types in either interval may mean that the stimuli were not sufficiently similar or dissimilar to cause any difference in performance. However, the stimulus pairs employed in the current study were the same as those successfully used by the above mentioned authors.

Recall that Wood (1974) presented his stimuli in both modalities and therefore his differences between phonologically similar and visually similar pairs in the two ISI's were probably larger and more consistent. His subjects were forced to code in either one or another dimension, and therefore the similarity was probably more disruptive than in the present study. Dainoff (1970), on the other hand, used only the visual mode, and still found that RT's to aurally confusable stimuli were longer than to non-confusable. However, the intervals employed in his study were 0, 1.125 and 1.5 seconds, and not all confusable stimulus pairs showed significantly increased RT's at the 1.125 second ISI, while they did so at the 1.5 second ISI. Perhaps longer ISI's would yield results similar to his.

However, in light of the lack of any significant difference between confusable and dissimilar pairs, it is difficult to conclude anything but that the young subjects were not disturbed by the similarity manipulation.

The elderly presented a somewhat different picture regarding the within group stimulus pair comparisons, although again, one that is somewhat unclear. The fact that visually similar pairs were significantly slower than phonologically similar pairs suggests that visual coding was impaired. However, one would then expect that visually confusable pairs would have slower reaction times than pairs which were dissimilar on both dimensions, and this was not found. Only stimulus pairs similar on both dimensions were significantly slower than those that were dissimilar.

In the 1 second interval, the RT's to phonologically similar pairs slowed to a greater degree than to visually similar stimuli, eliminating the significant difference between the two. While this is indicative of a trend toward phonological coding, there is no conclusive support, since performance for aurally similar pairs was not significantly slower than for visually similar pairs, or for dissimilar pairs. Again, only RT's to pairs similar in both dimensions were slower than those which were dissimilar.

In sum, these data demonstrate a susceptibility to combined phonological and visual interference, and suggest a vulnerability to visual interference in the slower interval, on the part of elderly subjects.

Experiment 5

Using the same basic procedure, a second study was conducted in which the ISI's were simultaneous display, .5, 1.5 and 2 seconds. It was thought that perhaps the .5 and 1 second ISI's employed in Experiment 4 may represent transitional points during in the shift from visual to auditory coding. With simultaneous presentation, the degree of visual coding and visual confusion is expected to be larger than with the sequential presentation. Conversely, phonological coding should predominate with the 2 second ISI, and hence the phonological confusion effect should be greatest.

In addition, sub-vocalization and rehearsal were eliminated or greatly reduced in one condition by requiring subjects to repeat the word "the" during stimulus presentation and their responses. Typically, when eliminating or reducing sub-vocalization or rehearsal, aurally confusable stimuli are less disruptive (Hitch, Woodin and Baker, 1989; Salame and Baddeley, 1982). Suppression, then, should result in a reduction of the phonological confusion effect. Where coding is predominantly phonological, this should translate to a return of the visual confusion effect. If elderly subjects are less adept at visual coding, and more dependent upon phonological coding and articulatory processes, then blocking these at the longer ISI's should result in a greater visual confusion than that seen in young subjects.

Method

Subjects

Subjects were 12 young and 12 elderly students recruited from the Hunter College student body. Young subjects ranged in age from 18 to 27 years with a mean age of 22.33 years. Elderly subject ages were between 62 and 72, the mean age being 66.88 years. Young subjects were undergraduates; most of the elderly held a B.A. or a B.S. degree. Two had completed their masters, while two had only finished high school and had worked in the business world for many years. Mini Mental scores for the young averaged 29.83, while those of the elderly averaged 29.42. Again, no one scoring below 27 was included in the study.

Stimuli and Design

The same stimuli and list constructions were employed.

However, there were four list and four Interval conditions: simultaneous display, .5, 1.5, and 2.0 seconds. Therefore, within each age group 3 subjects were randomly assigned to each row of a 4 X 4 greco-latin square. Half of the subjects received the suppression condition first.

Apparatus and Procedure

These were the same as in the first experiment with the exception that a simultaneous presentation was now included. The two letters appeared together in the center of the screen, separated by the width of one space. Stimulus duration was 660 ms for this condition, in order to equalize the viewing time between this and the sequential presentation (letters visible for 330 ms each). Response timing began after this time elapsed.

Results

Comparison of overall performance of both age groups showed the young to have faster reaction times than the elderly, $t(22) = -3.50$, $p < .0001$. Because of the inclusion of the suppression condition, as well as the addition of two more intervals, it was decided to perform separate ANOVA's for each age group; the data for young subjects are displayed in Table 20.

Young. A 2 (Suppression) X 4 (Interval) X 5 (Stimulus Type) ANOVA for the young yielded a significant main effect of Interval, $F(3,33) = 7.40$, $MS_e = 33338$, $p = .0006$, chiefly attributable to the slower performance for the simultaneous than for the .5 second and the 1.5 second ISI (Duncan multiple range test, $\underline{R}_4$ = 74.99). A marginally significant main effect of Stimulus Type was obtained, $\underline{F}(4,44)$ = 2.46, $\underline{MS}_e$ = 12866, $\underline{p}$ = .0619, the basis of which was most probably RT's having been slower to the HAHV than to the other pair types.

A Duncan multiple range test showed that a significant Interval X Stimulus Type interaction, $\underline{F}(3,132)$ = 1.85, $\underline{MS}_e$ = 8084, $\underline{p}$ = .05, is carried by slower RT's in the simultaneous interval for most, but not all, of the stimulus pair types.

Within-Interval Pair Type Comparisons: Non-suppression. The same within ISI comparisons made in Experiment 1 were made for each condition, and $\underline{t}$ ratios are displayed in Table 21.

Again, strong evidence of coding in either one or the other dimension would require two significant comparisons: the aurally similar vs. visually similar, and either the aurally similar vs. the dissimilar, or the visually similar vs. dissimilar comparison, depending on the nature of the first comparison. Weak evidence for coding in one particular dimension would consist of one of the last two comparisons being significant, depending on the nature of the first.

An inspection of the tabled $\underline{t}$ ratios for the young subjects shows that there is no strong evidence of coding

Table 20

Mean[a] Reaction Times (ms) of Same/Different Judgements of Letter Pairs of Young Subjects in All Conditions in Experiment 5.

	HALV	LAHV	HAHV	LALV	SAME	Mean
Nonsupression						
Simultaneous	924	939_a	1004_a	986_a	1009_a	972.20
0.5 sec ISI	878	810_b	902_b	859_b	858_b	861.40
1.5 sec ISI	914	955_a	972_a	863_b	909_b	922.60
2.0 sec ISI	945	951_a	994_a	917_b	908_b	943.00
Mean	915.25	913.75	967.75	906.25	921.00	
Suppression						
Simultaneous	940_a	916_a	983_a	996_a	1031_a	973
0.5 sec ISI	854_b	849	907	861_b	851_b	864
1.5 sec ISI	880	832_b	877_b	873_b	861_b	865
2.0 sec ISI	897	921_a	900_b	869_b	884_b	894
Mean	892.75	879.50	916.75	899.75	906.75	899.00

Note. Means with different subscripts differ significantly within a pair type at $p<.05$ by the Duncan multiple - range test.

aMedian RT's were calculated. Entries represent the mean of the medians.

Table 21

Within Interval Comparisons (t - Ratios) of Reaction Times to Various Pair Types for Young Subjects in Experiment 5.

	HALV, LAHV	HALV, LALV	LAHV, LALV	HAHV, LALV
Nonsuppression				
Simultaneous	1.56	- 2.30	2.43*	0.63
0.5 sec ISI	2.29*	0.66	-2.15	1.67
1.5 sec ISI	1.20	2.79*	2.76*	4.02*
2.0 sec ISI	0.62	0.68	0.81	1.72
Suppression				
Simultaneous	1.36	0.69	0.58	1.25
0.5 sec ISI	0.38	0.43	0.76	1.24
1.5 sec ISI	1.00	0.25	0.98	0.12
2.0 sec ISI	0.58	1.33	2.10*	1.87*

*$p < .05$.

in either one or another dimension.

In the simultaneous presentation condition, there is some indication that visual coding was disturbed, and in the .5 second ISI, phonological similarity seems to have been somewhat disruptive.

In the 1.5 second ISI, the interval in which the most significant differences occurred, the suggestion is that both auditory and visual similarity slowed RT's, but that neither was dominant over the other.

For the 2.0 second ISI, no individual similarity type had a significant effect on performance.

Within-Interval Suppression Comparisons. While articulatory suppression seems to have eliminated significant comparisons in the first three intervals, two significant differences in performance appeared in the 2.0 second ISI. Apparently, visual similarity types were problematic in this condition, as visually similar RT's were slower than dissimilar RT's, as were RT's to the dual similarity pairs. This would be expected with the reduction of phonological coding. Although with this last pair type, the involvement of phonological confusion cannot be altogether ruled out.

Errors. The number of errors was quite low. Recall that each subject had a total of 144 trials per interval. In the non-suppression condition, for the simultaneous condition there was a total number of 4 errors; for the .5

second ISI there were 3 errors; in the 1.5 second ISI there were 2 errors, and in the 2.0 second interval the total number of errors was 2.

In the suppression condition, for simultaneous presentation, there was a total of 6 errors; in the .5 second ISI there were 3; in the 1.5 second ISI there were 4, and in the 2.0 there were 9.

Elderly. The reaction times for the elderly in all conditions are presented in Table 22.

A 2 (Suppression) X 4 (Interval) X 5 (Stimulus Type) ANOVA for the elderly group showed significant main effects of Suppression, $F(1,11) = 7.06$, $MS_e = 146757$, p .0233; Interval, $F(3,33) = 8.11$, $MS_e = 82417$, $p = .0003$, and Stimulus Type, $F(4,44) = 9.19$, $MS_e = 16252$, $p < .0000$).

The main effect of Suppression was due to significantly faster reaction times under suppression than non-suppression for this age group. The main effect of Interval was of the same nature as that seen in the young ANOVA, with the greatest difference among the intervals having occurred between the simultaneous presentation condition and .5 second ISI (Duncan multiple range test shown in Table 22), and the main effect of Stimulus Type is the result of faster RT's in LALV as compared to HAHV pair types (Duncan multiple range test, $R_5 = 77.80$, not shown in Table 22).

Significant Dunnett tests (C - E = 69.87) indicate that RT improved under suppression for the simultaneous

Table 22

Mean[a] Reaction Times (ms) of Same/Different Judgements of Letter Pairs of Elderly in all Conditions in Experiment 5.

	HALV	LAHV	HAHV	LALV	SAME	Mean
Nonsupression						
Simultaneous	1186_a	1281_a	1327_a	1219_a	1298_a	1262.20
0.5 sec ISI	1027_b	1066_c	1079_c	1015_c	1097_c	1056.80
1.5 sec ISI	1109	1202_b	1198_b	1096_b	1160_b	1153.00
2.0 sec ISI	1151_a	1173_b	1235_b	1126_b	1201_b	1177.20
Mean	1118.25	1180.50	1209.75	1114.00	1189.00	
Suppression						
Simultaneous	1152_a	1215_a	1221_a	1093_a	1211_a	1178.40*
0.5 sec ISI	1019_b	1040_b	1065_b	949_b	1092_b	1033.00
1.5 sec ISI	1027_b	1067_b	1067_b	1014_b	1067_b	1048.40*
2.0 sec ISI	1006_b	1020_b	1046_b	983_b	1057_b	1022.40*
Mean	1051.00	1085.50	1099.75	1009.75	1106.75	

Note. Means with different subscripts differ significantly within a pair type at $p < .05$ by the Duncan multiple - range test.

[a]Median RT's were calculated. Entries represent the mean of the medians.

* Denotes a significant Dunnett test; C - E = 69.82.

presentation, the 1.5 second, and the 2.0 second interval.

Within-Interval Non-suppression Comparisons. Table 23 displays the comparisons for elderly subjects.

The significant comparisons necessary to allow strong inference of either phonological or visual coding are not present in any one interval.

In the simultaneous presentation, there is a suggestion of phonological interference, since phonologically similar RT's were slower than visually similar RT's, but the phonologically similar pairs were not slower than the dissimilar pairs. Additionally, RT's to stimulus pairs which were similar on both dimensions were slower than those of dissimilar pairs, suggesting that the phonological element may have been involved in the slower RT's, but again, the visual similarity cannot be ruled out as a factor. In the .5 second ISI, only RT's to stimulus pairs with dual similarity were slower than those to dissimilar pairs, suggesting that both levels were necessary to have an effect.

As was the case with young subjects, the 1.5 second ISI seems to have been the most affected by similarity types, although the pattern of interference was not quite the same for both groups. However, the significant comparisons suggest, as they do for young subjects, that both phonological and visual interference had a negative effect on performance. In the 2.0 second ISI, visually similar

Table 23

Within Interval Comparisons (T - Ratios) of Reaction Times to Various Pair Types for Elderly Subjects in Experiment 5.

	HALV, LAHV	HALV, LALV	LAHV, LALV	HAHV, LALV
Nonsuppression				
Simultaneous	2.28*	0.73	1.14	2.58*
0.5 sec ISI	1.23	0.42	1.75	1.81*
1.5 sec ISI	1.86*	0.61	2.12*	3.91*
2.0 sec ISI	1.09	1.40	2.03*	1.62
Suppression				
Simultaneous	1.90*	2.00*	6.39*	4.47*
0.5 sec	0.49	1.00	2.66*	2.24*
1.5 sec	1.98*	0.43	1.44	1.54
2.0 sec	1.50	0.55	0.90	2.35*

*$p < .05$.

RT's were slower than those of dissimilar pairs and again, the dual similarity RT's are also slower than the dissimilar, suggesting the involvement of visual confusion, but not precluding phonological.

Within-Interval Suppression Comparisons. Unlike the young data, the suppression condition did not seem to reduce the significant differences between pair types.

For the simultaneous presentation, all comparisons were significantly different, suggesting again that both visual and phonological interference were present. Only the dual similarity pairs have an effect in the .5 second interval. The 1.5 second ISI seems to be less disturbed under suppression, but there is little indication of the type of coding. In the 2.0 second ISI, only the dual similarity seems to have had an effect.

Thus, it appears that the simultaneous presentation was more susceptible to similarity under suppression than was sequential presentation. However, an inspection of the data shows that the increase in significant comparisons in this interval was due to the greater decrease in RT under suppression for the totally dissimilar pairs (LALV) than for the similar pairs involved in the additionally significant comparisons (HALV and LAHV). Thus, the differences between them were increased.

Errors. Again, the number of errors was low. For non-suppression, in the simultaneous display condition, there were two errors; in the .5 second ISI there were 4; in the 1.5 second ISI 9 errors were made, and there were 8 errors in 2.0 second interval.

For suppression, in the simultaneous display there were 10; in the .5 second ISI 7 errors were made; in the 1.5 second ISI there were 4, and in the 2.0 second interval there were 9.

Young Vs. Elderly Error Analyses. A comparison of overall misses and FA proportions for young and elderly the showed that there was no significant difference in either misses, $t(22) = -.96$, $p <.05$), or FA's, $t(22) = -1.45$, $p < .05$.

Discussion

The reaction times of both age groups were generally slower in the simultaneous display condition as compared to the sequential presentation conditions. This is most likely because in sequential presentation, one letter appeared for a specified interval and was then followed by another interval, both of which allowed the subject to encode and prepare to make the match as soon as the second stimulus was presented, at which point the timing began. That is, the reading of the first member of the pair was not timed.

When the stimuli were presented together, subjects were required to read and encode both stimuli while being timed. Therefore, the RT's to simultaneous displays were longer than to sequential presentations.

Posner et al (1969) and Dainoff (1970) also reported slower RT's to stimuli presented at 0 second intervals than to those presented with an ISI greater than 0 seconds.

While both young and elderly showed an overall effect of slower RT's to the dual similarity as compared with the totally dissimilar types, only the elderly effect was significant, suggesting that they were more susceptible to this similarity manipulation than were the young.

Suppression as a main effect significantly improved performance for the elderly, and a similar trend was noted in the data of the young. One plausible interpretation of this, especially in light of the findings of the previous studies reported in this paper, is that the task of suppressing articulation may allow elderly subjects, who are more prone to distraction and unable to inhibit attending to task irrelevant stimuli, (Hasher & Zacks, 1988; Mc Dowd and Filion, 1992) to focus better on the task at hand by preventing distractibility from internally or externally generated noise. Additional support for this interpretation comes from the fact that the improvement in performance is greater at the longer ISI's, during which distractibility would be more likely to occur. Clearly, further investigation of this phenomenon is warranted.

Within interval comparisons of RT's to the various pair types proved to be somewhat inconclusive with respect to establishing either phonological or visual coding at each interval. In general, susceptibility to both types of similarity seemed to be the mode for young and elderly. There was a suggestion of visual coding on the part of the young and phonological coding on the part of the elderly at the simultaneous presentation in the non-suppression condition.

Under suppression, the young performance seemed to become somewhat impervious to the similarity manipulation, while that of the elderly remained susceptible.

Both Experiments 4 and 5 failed to fully replicate Dainoff (1970), who found that RT's were longer for phonologically confusable letters than for the non-confusable letter pairs, and that this effect increased as the length of the ISI was increased. This was clearly not the case in the current studies. Although phonological confusion did slow reaction times, the effect was not progressive and stronger at the longer intervals. In fact, visual confusion seemed to be present more often for both young and elderly, regardless of the interval. However, these effects were not consistently and exclusively present at the shorter ISI's.

As was mentioned above, the confusable letters employed here were the same as those used by Dainoff (1970) and Wood (1974), and therefore, failure to achieve consistent and reliable phonological confusion effects at the longer ISI's cannot be attributed to an ineffective similarity manipulation. Rather, the difference may be in the instructions to the subjects.

Posner and Mitchell (1967) found that the time advantage of the physical over the name match was present only if subjects were specifically instructed to make their judgements based on the name. When judged by appearance, the differences in response time for physically identical vs. dissimilar pairs was not present. The studies of Posner et. al. (1969) which manipulated ISI's also employed instructions to match on a name basis. Although Dainoff (1970) did not specify the instructions given to his subjects, presumably he too used them, since he considers parts of his experiment to be a direct replication of Posner et al. (1969).

These studies did not specify the basis upon which the match was to be made. It was believed that subjects would adopt their own basis, and that perhaps the bases of the two age groups might differ. Also, articulatory supression was to have shifted coding the direction of the visual dimension.

Since in general, both visual and phonological confusion was present in varying degrees, it may be inferred that both dimensions of coding were used, and that there seemed to be no age related differences in type of coding employed.

Conclusion

These studies attempted to converge upon age differences in coding, recoding, selective attention, and response inhibition in young and normal elderly subjects using three different paradigms. The most salient findings with regard to these issues and some general observations of the 5 studies may be briefly summed up as follows:

With respect to coding and recoding, these data suggest that elderly subjects depend more upon a phonological and code and related articulatory processes than do young. Visually related deficits were only seen indirectly, in that elderly seemed to have more difficulty than young subjects in recalling visually presented stimuli in an oral mode, andappeared to have been more susceptible to visual suffix effects, especially when required to recall aloud.

Although for the most part, both age groups exhibited standard serial position effects, serial recall in general was more difficult for older subjects, despite their letter spans being very close to those of the young subjects. Throughout the immediate recall experiments, young subjects' end-of-sequence performance consistently surpassed that of the elderly. Again, this is in agreement with Taub (1972) who found that young and elderly subjects with equivalent Forward Digit spans did not perform equally well on others which were different, but related. One might speculate that the requirement of encoding positional, as well as content information might require more processing resources of the elderly. Yet these requirements must also be met in the Forward Digit Span task, and as mentioned above, research shows there to be little, if any, decline in this measure over the life span. It is possible that the difference lies in the use of letters as opposed to numbers, alphabetic stimuli having greater potential for various types of associations than numeric. But again, the span measure employed in these studies used letters, and the greatest difference between age groups at any one time was less than half of a letter; Botwinick and Storandt (1974) reported auditory letter spans of young subjects to be between six and seven letters, while those of the elderly were between five and six. Perhaps the greater number of trials in the actual experiment as opposed to the letter span measure was a factor, in that elderly may be less able to sustain a particular performance level, due to waning attention. Allen and Crozier (1992) studied age and ideal chunk size using a serial recall paradigm, and found that while both young and elderly were equally efficient in chunking, the elderly recalled fewer correct sequences than the young. They considered the possibility of internal noise impairing short term memory processes, and also noted that an age related increase in within-chunk transpositional errors would fit with an interpretation of age related attentional deficits.

An attentional type of deficit is clearly demonstrated by the elderly's lesser ability to selectively attend to the list of letters and to exclude the suffixes from their responses, as well as by their increase in extra list, as well as suffix intrusions errors in this condition. That is, the failure of an attention system, that of inhibition, may be inferred. It is worth noting that neurophysiological correlates of age related diminished inhibitory action abound, and Prinz, Dustman & Emmerson (1990), in their review of them, note that "Difficulty in suppressing ongoing motoric and mental activity might contribute to impulsiveness, behavioral rigidity, or a relative inability to quickly shift from one cognitive activity to another [mental inflexibility]" p.141).

Likewise, removing articulation, and therefore rehearsal of the non-confusable letter lists in Experiment 3, was far more detrimental to elderly serial recall performance than to that of the young.

While the intrusions obtained in these studies were not overwhelmingly large in number, they were consistent and somewhat unexpected. Indeed evidence exists that intrusion errors are most often seen in clinical populations (See, for example, Shindler, Caplan & Hier, 1984). Yet, intrusion errors have been obtained in young (e.g., Cole & Young, 1975; Drewnowski & Murdock, 1980) as well as normal elderly groups (Hartikainen, Soinen, Partanen, Helkala & Riekkinen, 1992). Again, paradigmatic and procedural differences may be important in uncovering such errors.

Further, the phonological/alphabetic order type of intrusions committed in both the suffix and the confusable recall paradigms suggests that phonological competitive elements may be more prevalent in elderly than in young working memory.

The significant improvement seen in elderly reaction time (and to a lesser, insignificant degree in the young) under articulatory suppression in the similarity judgement paradigm, may indicate that when the task competitive elements were removed or reduced, performance on such a task that is minimally taxing to the working memory was improved. This is in contrast with the serial recall of confusable letters experiment, in which articulation was also suppressed. There the articulatory loop was compromised and the necessary rehearsal was prevented, resulting in poorer processing and recall.

Finally, future research in these areas should take into account the high motivation of the high functioning type of elderly persons who participated in our study. While we feel it is necessary to study individuals who are vital, involved, and less likely to be depressed, it is also necessary to design studies that minimize the opportunity to engage in compensatory strategies, such as referring to previously recorded lists, or using only blocked presentations, which may conceal certain deficiencies.

Also, an attempt to ascertain an older subject's knowledge of popular memory "remedies" might be made. Many of the elderly in our studies were quite knowledgeable with respect to the use of memory strategies. In fact, in response to post-experimental questions concerning strategies, more elderly than young reported the use of some strategy. Older subjects also reported changing strategies more often than the young, since in some cases, the use of some of these strategies, (often learned from self-help type books or T.V. programs) were counter productive (e.g., trying to associate initials of friends with each of the seven letters of a sequence, in a matter of 7 seconds). While it is certainly not desirable to discourage the use of strategy, it might be wise to formally and routinely collect information from all subjects, regarding the knowledge and use of it, and perhaps to even dissuade them from using the more elaborate types.

Appendix A
The Mini Mental State Test

Patient ______________________

Examiner______________________

Date ______________________

MINI MENTAL STATE

Score **Orientation**

( ) What is the (year) (season) (month) (date) (day)? (5 points)

( ) Where are we? (state) (county) (town) (hospital) (floor) (5 points)

Registration

( ) Name 3 objects: 1 second to say each. Then ask the patient to repeat all three after you have said them. 1 point for each correct. Then repeat them until he learns them. Count trials and record ______________. (3 points)

HAT, BAG, DISH

Attention and Calculation

( ) Serial 7's. 1 point for each correct. Stop at 5 answers. Or spell "world" backwards. (Number correct equals letters before first mistake – i.e., d l o r w = 2 correct). (5 points)

Recall

( ) Ask for the objects above. 1 point for each correct. (3 points)

Language Tests

( ) name – pencil, watch (2 points)

( ) repeat – no ifs, ands or buts (1 point)

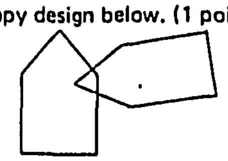
( ) follow a 3 stage command: "Take the paper in your right hand, fold it in half, and put it on the floor." (3 points)

Read and obey the following:

( ) CLOSE YOUR EYES. (1 point)

( ) Write a sentence spontaneously below. (1 point)

( ) Copy design below. (1 point)



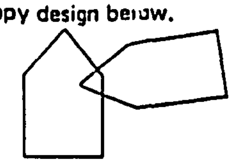
( ) TOTAL 30 POINTS

Read and obey the following:

( ) CLOSE YOUR EYES.

( ) Write a sentence spontaneously below.

( ) Copy design below.



Appendix B

Instructions to Subjects

Below are the instructions to subjects as they appeared in each condition.

Experiment 1: Auditory Control Written

YOUR TASK IS TO RECALL SOME LETTERS. YOU WILL HEAR A BEEP. SHORTLY AFTER, A SERIES OF LETTERS WILL APPEAR IN THE CENTER OF THE SCREEN, ONE AT A TIME. READ THE LETTERS ALOUD. YOU WILL BE ASKED TO RECALL THOSE LETTERS. YOUR SIGNAL TO BEGIN RECALLING THOSE LETTERS WILL BE A DASH (-). AFTER YOU SEE THE DASH, BEGIN WRITING DOWN THE LIST OF LETTERS IN THE ORDER IN WHICH THEY WERE GIVEN. DO NOT BEGIN WRITING UNTIL AFTER THE DASH. DO NOT WRITE DOWN THE DASH. IT IS JUST A SIGNAL TO BEGIN RECALLING THE LETTERS. IF YOU CANNOT REMEMBER A LETTER WHEN YOU COME TO IT PLEASE GUESS, BUT DO NOT GO BACK TO FILL IN ANY BLANK SPACES . WHEN YOU HEAR THE BEEP AGAIN YOU WILL KNOW THE NEXT LIST IS ABOUT TO BEGIN.
DO YOU HAVE ANY QUESTIONS?

Experiment 1: Auditory Control Spoken

YOUR TASK IS TO RECALL SOME LETTERS. YOU WILL HEAR A BEEP. SHORTLY AFTER, A SERIES OF LETTERS WILL APPEAR IN THE CENTER OF THE SCREEN, ONE AT A TIME. READ THE LETTERS ALOUD. YOU WILL BE ASKED TO RECALL THOSE LETTERS. YOUR SIGNAL TO BEGIN RECALLING THOSE LETTERS WILL BE A DASH (-). AFTER YOU SEE THE DASH, BEGIN RECALLING THE LETTERS ALOUD, THE ORDER IN WHICH THEY WERE GIVEN. DO NOT BEGIN RECALLING UNTIL AFTER

THE DASH. DO NOT RECALL THE DASH. IT IS JUST A SIGNAL TO BEGIN RECALLING THE LETTERS. IF YOU CANNOT REMEMBER A LETTER WHEN YOU COME TO IT PLEASE GUESS. WHEN YOU HEAR THE BEEP AGAIN YOU WILL KNOW THE NEXT LIST IS ABOUT TO BEGIN. DO YOU HAVE ANY QUESTIONS?

Experiment 1: Auditory Suffix Written

YOUR TASK IS TO RECALL SOME LETTERS. YOU WILL HEAR A BEEP. SHORTLY AFTER, A SERIES OF LETTERS WILL APPEAR IN THE CENTER OF THE SCREEN, ONE AT A TIME. READ THE LETTERS ALOUD. YOU WILL BE ASKED TO RECALL THOSE LETTERS. YOUR SIGNAL TO BEGIN RECALLING THOSE LETTERS WILL BE THE LETTER V OR THE LETTER Y. AFTER YOU SEE THE LETTER V OR Y, BEGIN WRITING DOWN THE LIST OF LETTERS IN THE ORDER IN WHICH THEY WERE GIVEN. DO NOT BEGIN WRITING UNTIL AFTER THE LETTER V OR Y. DO NOT WRITE DOWN THE LETTERS V OR Y. THEY ARE JUST A SIGNAL TO BEGIN RECALLING THE LETTERS. IF YOU CANNOT REMEMBER A LETTER WHEN YOU COME TO IT PLEASE GUESS, BUT DO NOT GO BACK TO FILL IN ANY BLANK SPACES . WHEN YOU HEAR THE BEEP AGAIN YOU WILL KNOW THE NEXT LIST IS ABOUT TO BEGIN. DO YOU HAVE ANY QUESTIONS?

Experiment 1: Auditory Suffix Spoken

YOUR TASK IS TO RECALL SOME LETTERS. YOU WILL HEAR A BEEP. SHORTLY AFTER, A SERIES OF LETTERS WILL APPEAR IN THE CENTER OF THE SCREEN, ONE AT A TIME. READ THE LETTERS ALOUD. YOU WILL BE ASKED TO RECALL THOSE LETTERS. YOUR SIGNAL TO BEGIN RECALLING THOSE LETTERS WILL BE THE LETTER V OR THE LETTER

Y. AFTER YOU SEE THE DASH, BEGIN RECALLING THE LETTERS ALOUD, IN THE ORDER IN WHICH THEY WERE GIVEN. DO NOT BEGIN RECALLING UNTIL AFTER THE DASH. DO NOT RECALL THE LETTERS V OR Y. THEY ARE JUST SIGNALS TO BEGIN RECALLING THE SERIES OF LETTERS. IF YOU CANNOT REMEMBER A LETTER WHEN YOU COME TO IT PLEASE GUESS. WHEN YOU HEAR THE BEEP AGAIN YOU WILL KNOW THE NEXT LIST IS ABOUT TO BEGIN. DO YOU HAVE ANY QUESTIONS?

Experiment 1: Visual Control Written

YOUR TASK IS TO RECALL SOME LETTERS. YOU WILL HEAR A BEEP. SHORTLY AFTER, A SERIES OF LETTERS WILL APPEAR IN THE CENTER OF THE SCREEN, ONE AT A TIME. READ THE LETTERS SILENTLY. YOU WILL BE ASKED TO RECALL THOSE LETTERS. YOUR SIGNAL TO BEGIN RECALLING THOSE LETTERS WILL BE A DASH (-). AFTER THE DASH, BEGIN WRITING DOWN THE LIST OF LETTERS IN THE ORDER IN WHICH THEY WERE GIVEN. DO NOT BEGIN WRITING UNTIL AFTER THE DASH. DO NOT WRITE DOWN THE DASH. IT IS JUST A SIGNAL TO BEGIN RECALLING THE LETTERS. IF YOU CANNOT REMEMBER A LETTER WHEN YOU COME TO IT PLEASE GUESS, BUT DO NOT GO BACK TO FILL IN ANY BLANK SPACES . WHEN YOU HEAR THE BEEP AGAIN YOU WILL KNOW THE NEXT LIST IS ABOUT TO BEGIN. DO YOU HAVE ANY QUESTIONS?

Experiment 1: Visual Control Spoken

YOUR TASK IS TO RECALL SOME LETTERS. YOU WILL HEAR A BEEP. SHORTLY AFTER, A SERIES OF LETTERS WILL APPEAR IN THE CENTER OF THE SCREEN, ONE AT A TIME. READ THE LETTERS SILENTLY. YOU WILL BE ASKED TO RECALL THOSE LETTERS. YOUR SIGNAL TO BEGIN

RECALLING THOSE LETTERS WILL BE A DASH (-). AFTER THE DASH, BEGIN RECALLING THE LETTERS ALOUD, IN THE ORDER IN WHICH THEY WERE GIVEN. DO NOT BEGIN RECALLING UNTIL AFTER THE DASH. DO NOT RECALL THE DASH. IT IS JUST A SIGNAL TO BEGIN RECALLING THE LETTERS. IF YOU CANNOT REMEMBER A LETTER WHEN YOU COME TO IT PLEASE GUESS. WHEN YOU HEAR THE BEEP AGAIN YOU WILL KNOW THE NEXT LIST IS ABOUT TO BEGIN. DO YOU HAVE ANY QUESTIONS?

Experiment 1: Visual Suffix Written

YOUR TASK IS TO RECALL SOME LETTERS. YOU WILL HEAR A BEEP. SHORTLY AFTER, A SERIES OF LETTERS WILL APPEAR IN THE CENTER OF THE SCREEN, ONE AT A TIME. READ THE LETTERS SILENTLY. YOU WILL BE ASKED TO RECALL THOSE LETTERS. YOUR SIGNAL TO BEGIN RECALLING THOSE LETTERS WILL BE THE LETTER V OR THE LETTER Y. AFTER THE LETTER V OR Y, BEGIN WRITING DOWN THE LIST OF LETTERS IN THE ORDER IN WHICH THEY WERE GIVEN. DO NOT BEGIN WRITING UNTIL AFTER THE LETTER V OR Y. DO NOT WRITE DOWN THE LETTERS V OR Y. THEY ARE JUST SIGNALS TO BEGIN RECALLING THE LETTERS. IF YOU CANNOT REMEMBER A LETTER WHEN YOU COME TO IT PLEASE GUESS, BUT DO NOT GO BACK TO FILL IN ANY BLANK SPACES . WHEN YOU HEAR THE BEEP AGAIN YOU WILL KNOW THE NEXT LIST IS ABOUT TO BEGIN. DO YOU HAVE ANY QUESTIONS?

Experiment 1: Visual Suffix Spoken

YOUR TASK IS TO RECALL SOME LETTERS. YOU WILL HEAR A BEEP. SHORTLY AFTER, A SERIES OF LETTERS WILL APPEAR IN THE CENTER OF THE SCREEN, ONE AT A TIME. READ THE LETTERS SILENTLY. YOU

WILL BE ASKED TO RECALL THOSE LETTERS. YOUR SIGNAL TO BEGIN RECALLING THOSE LETTERS WILL BE THE LETTER V OR THE LETTER Y. AFTER THE LETTER V OR Y, BEGIN RECALLING THE LIST OF LETTERS ALOUD, IN THE ORDER IN WHICH THEY WERE GIVEN. DO NOT BEGIN RECALLING UNTIL AFTER THE LETTER V OR Y. DO NOT RECALL THE LETTERS V OR Y. THEY ARE JUST SIGNALS TO BEGIN RECALLING THE SERIES OF LETTERS. IF YOU CANNOT REMEMBER A LETTER WHEN YOU COME TO IT PLEASE GUESS. WHEN YOU HEAR THE BEEP AGAIN YOU WILL KNOW THE NEXT LIST IS ABOUT TO BEGIN. DO YOU HAVE ANY QUESTIONS?

Experiment 2: Auditory Non Suffix Written

YOUR TASK IS TO RECALL SOME LETTERS. YOU WILL HEAR A BEEP. SHORTLY AFTER, YOU WILL HEAR A SERIES OF LETTERS. YOU WILL THEN BE ASKED TO RECALL THOSE LETTERS. YOUR SIGNAL TO BEGIN RECALLING THE LETTERS WILL BE A CLICK. WHEN YOU HEAR THE CLICK, BEGIN WRITING DOWN THE LETTERS , IN THE ORDER IN WHICH THEY WERE GIVEN. DO NOT BEGIN WRITING UNTIL AFTER YOU HAVE HEARD THE CLICK. IF YOU CANNOT REMEMBER A LETTER WHEN YOU COME TO IT, PLEASE GUESS, BUT DO NOT GO BACK TO FILL IN BLANK SPACES. WHEN YOU HEAR THE BEEP AGAIN YOU WILL KNOW THE NEXT SERIES OF LETTERS IS ABOUT TO BEGIN. DO YOU HAVE ANY QUESTIONS?

Experiment 2: Auditory Non Suffix Spoken

YOUR TASK IS TO RECALL SOME LETTERS. YOU WILL HEAR A BEEP. SHORTLY AFTER, YOU WILL HEAR A SERIES OF LETTERS. YOU WILL THEN BE ASKED TO RECALL THOSE LETTERS. YOUR SIGNAL TO BEGIN

RECALLING THE LETTERS WILL BE A CLICK. WHEN YOU HEAR THE CLICK, BEGIN RECALLING THE LIST OF LETTERS ALOUD, IN THE ORDER IN WHICH THEY WERE GIVEN. DO NOT BEGIN RECALLING UNTIL AFTER YOU HAVE HEARD THE CLICK. IF YOU CANNOT REMEMBER A LETTER WHEN YOU COME TO IT, PLEASE GUESS. WHEN YOU HEAR THE BEEP AGAIN YOU WILL KNOW THE NEXT SERIES OF LETTERS IS ABOUT TO BEGIN. DO YOU HAVE ANY QUESTIONS?

Experiment 2: Auditory Suffix Written

YOUR TASK IS TO RECALL SOME LETTERS. YOU WILL HEAR A BEEP. SHORTLY AFTER, YOU WILL HEAR A SERIES OF LETTERS. YOU WILL THEN BE ASKED TO RECALL THOSE LETTERS. YOUR SIGNAL TO BEGIN RECALLING THE LETTERS WILL BE THE LETTER F OR THE LETTER P. WHEN YOU HEAR THE LETTER F OR P, BEGIN WRITING DOWN THE LETTERS, IN THE ORDER IN WHICH THEY WERE GIVEN. DO NOT BEGIN WRITING UNTIL AFTER YOU HAVE HEARD THE LETTER F OR P. IF YOU CANNOT REMEMBER A LETTER WHEN YOU COME TO IT, PLEASE GUESS, BUT DO NOT GO BACK TO FILL IN BLANK SPACES. DO NOT WRITE DOWN THE LETTER F OR P. THESE ARE JUST SIGNALS TO BEGIN RECALLING THE PRECEDING LETTERS. WHEN YOU HEAR THE BEEP AGAIN YOU WILL KNOW THE NEXT SERIES OF LETTERS IS ABOUT TO BEGIN. DO YOU HAVE ANY QUESTIONS?

Experiment 2: Auditory Suffix Spoken

YOUR TASK IS TO RECALL SOME LETTERS. YOU WILL HEAR A BEEP. SHORTLY AFTER, YOU WILL HEAR A SERIES OF LETTERS. YOU WILL THEN BE ASKED TO RECALL THOSE LETTERS. YOUR SIGNAL TO BEGIN RECALLING THE LETTERS WILL BE THE LETTER F OR THE LETTER P.

WHEN YOU HEAR THE LETTER F OR THE LETTER P, BEGIN RECALLING ALOUD THE LIST OF LETTERS, IN THE ORDER IN WHICH THEY WERE GIVEN. DO NOT BEGIN RECALLING UNTIL AFTER YOU HAVE HEARD THE LETTER F OR P. IF YOU CANNOT REMEMBER A LETTER WHEN YOU COME TO IT, PLEASE GUESS. DO NOT RECALL THE LETTER F OR P. THESE ARE JUST SIGNALS TO BEGIN RECALLING THE PRECEDING LETTERS. WHEN YOU HEAR THE BEEP AGAIN YOU WILL KNOW THE NEXT SERIES OF LETTERS IS ABOUT TO BEGIN. DO YOU HAVE ANY QUESTIONS?

Experiment 3: Non Suppression

YOUR TASK IS TO RECALL SOME LETTERS. YOU WILL HEAR A BEEP. SHORTLY AFTER, A SERIES OF LETTERS WILL APPEAR IN THE CENTER OF THE SCREEN, ONE AT A TIME. READ THE LETTERS SILENTLY. YOU WILL BE ASKED TO RECALL THOSE LETTERS. AFTER THE LAST LETTER, BEGIN WRITING DOWN THE LIST OF LETTERS IN THE ORDER IN WHICH THEY WERE GIVEN. DO NOT BEGIN WRITING UNTIL AFTER THE LAST LETTER HAS APPEARED. IF YOU CANNOT REMEMBER A LETTER WHEN YOU COME TO IT, PLEASE GUESS, BUT DO NOT GO BACK TO FILL IN BLANK SPACES. WHEN YOU HEAR THE BEEP AGAIN YOU WILL KNOW THE NEXT LIST OF LETTERS IS ABOUT TO BEGIN. DO YOU HAVE ANY QUESTINSTRUCTIONS EXPERIMENT 3

Experiment 3: Suppression

YOUR TASK IS TO RECALL SOME LETTERS. YOU WILL HEAR A BEEP. AS SOON AS YOU HEAR THE BEEP, BEGIN SAYING THE WORD "THE" OUT LOUD, AND KEEP SAYING IT. SHORTLY AFTER, A SERIES OF LETTERS WILL APPEAR IN THE CENTER OF THE SCREEN, ONE AT A

TIME. READ THE LETTERS. WHILE YOU ARE READING THE LETTERS IT IS NECESSARY THAT YOU CONTINUE TO REPEAT THE WORD "THE". YOU WILL BE ASKED TO RECALL THOSE LETTERS. AFTER THE LAST LETTER, BEGIN WRITING DOWN THE LIST OF LETTERS IN THE ORDER IN WHICH THEY WERE GIVEN. YOU WILL CONTINUE TO SAY THE WORD "THE" WHILE YOU ARE WRITING. DO NOT BEGIN WRITING UNTIL AFTER THE LAST LETTER HAS APPEARED. IF YOU CANNOT REMEMBER A LETTER WHEN YOU COME TO IT, PLEASE GUESS, BUT DO NOT GO BACK TO FILL IN BLANK SPACES. WHEN YOU HEAR THE BEEP AGAIN YOU WILL KNOW THE NEXT LIST OF LETTERS IS ABOUT TO BEGIN. DO YOU HAVE ANY QUESTIONS?

Experiment 4

YOUR TASK IS TO JUDGE IF TWO LETTERS ARE THE SAME OR DIFFERENT. THE LETTERS WILL APPEAR IN THE CENTER OF THE SCREEN, ONE AT A TIME. AS SOON AS THE SECOND LETTER APPEARS, PRESS THE BUTTON MARKED "S" IF THEY ARE THE SAME OR PRESS THE BUTTON MARKED "D" IF THEY ARE DIFFERENT. BE SURE TO RESPOND AS QUICKLY AS POSSIBLE, USING ONLY YOUR INDEX FINGER. AFTER YOU HAVE PRESSED THE BUTTON, RETURN YOUR FINGER TO THE GREEN DOT BELOW THE BUTTONS. LOOK UP AT THE SCREEN TO WATCH FOR THE NEXT PAIR OF LETTERS. DO YOU HAVE ANY QUESTIONS?

Experiment 5: Non Suppression

YOUR TASK IS TO JUDGE IF TWO LETTERS ARE THE SAME OR DIFFERENT. THE LETTERS WILL APPEAR IN THE CENTER OF THE SCREEN, ONE AT A TIME . IN ONE PART OF THE EXPERIMENT, THE

LETTERS WILL APPEAR TOGETHER. THE EXPERIMENTER WILL TELL YOU WHEN THIS IS GOING TO BE THE CASE. AS SOON AS THE SECOND LETTER APPEARS, PRESS THE BUTTON MARKED "S" IF THEY ARE THE SAME OR PRESS THE BUTTON MARKED "D" IF THEY ARE DIFFERENT. BE SURE TO RESPOND AS QUICKLY AS POSSIBLE, USING ONLY YOUR INDEX FINGER. AFTER YOU HAVE PRESSED THE BUTTON, RETURN YOUR FINGER TO THE GREEN DOT BELOW THE BUTTONS. LOOK UP AT THE SCREEN TO WATCH FOR THE NEXT PAIR OF LETTERS. DO YOU HAVE ANY QUESTIONS?

Experiment 5: Suppression

YOUR TASK IS TO JUDGE IF TWO LETTERS ARE THE SAME OR DIFFERENT. WHEN THE EXPERIMENTER TELLS YOU, BEGIN SAYING THE WORD "THE" OUT LOUD. THE LETTERS WILL THEN APPEAR IN THE CENTER OF THE SCREEN, ONE AT A TIME . IN ONE PART OF THE EXPERIMENT, THE LETTERS WILL APPEAR TOGETHER. THE EXPERIMENTER WILL TELL YOU WHEN THIS IS GOING TO BE THE CASE. CONTINUE TO SAY THE WORD "THE" THROUGHOUT THE EXPERIMENT. AS SOON AS THE SECOND LETTER APPEARS, PRESS THE BUTTON MARKED "S" IF THE LETTERS ARE THE SAME OR PRESS THE BUTTON MARKED "D" IF THEY ARE DIFFERENT. BE SURE TO RESPOND AS QUICKLY AS POSSIBLE, USING ONLY YOUR INDEX FINGER. AFTER YOU HAVE PRESSED THE BUTTON, RETURN YOUR FINGER TO THE GREEN DOT BELOW THE BUTTONS. LOOK UP AT THE SCREEN TO WATCH FOR THE NEXT PAIR OF LETTERS. CONTINUE TO SAY THE WORD "THE". IT IS NOT NECESSARY TO SAY "THE" IN A LOUD VOICE. DO NOT TRY AND SYNCHRONIZE IT WITH THE LETTERS THAT APPEAR ON THE

SCREEN. DO YOU HAVE ANY QUESTIONS?

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