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Age-Related Differences In Memory: The Role Of The Executive.

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AGE-RELATED DIFFERENCES IN MEMORY: THE ROLE OF THE EXECUTIVE

by

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A DISSERTATION

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ABSTRACT OF DISSERTATION
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Limitations in working memory capacity and executive capacity have both been proposed to explain age-related differences in memory. Executive flexibility has also been proposed as underlying performance deficits in older adults. This study tested a two-factor model of executive function including limitations in capacity and flexibility, along with limitations in working memory capacity.

A group of 24 young and 24 older adult subjects learned a series of four, 12-item picture lists. In each list subjects learned pictures sequentially, with speed of presentation under their control. The lists differed in the organization of items, with half of all subjects receiving lists which were similarly organized, and the other half receiving lists which varied between two patterns of organization. While learning each list, subjects also performed a secondary task in which they rehearsed a varying number of digits as a means of modulating, and measuring the capacity demands of the list learning task. Changes in each subjects' distribution of pause-time corresponding to changes in the organization of the to-be-learned material were used as a measure of flexibility.

Possible limitations were identified in working memory capacity, while no age-related deficits were found in either working memory capacity or executive capacity. Results were interpreted as indicating less executive flexibility in older adults under certain conditions, but differences in capacity and flexibility were not related to differences in performance. The group analysis of this data was discussed along with factors limiting the conclusions of this study.

Abstract Approved by: Committee Chairman Linda W. Duke

Program Director

Date 4/15/91 Dean of Graduate School

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DEDICATION

To my wife Kathy, and parents, Mary and Lloyd, whose endless support and patience allowed me to complete this project and fulfill a dream.

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LIST OF ABBREVIATIONS

AB	List Structure
CUB	Cubic
D	Digit Load
ED	Education
L	List Number
LIN	Linear
MEDS	Medications
MPT	Mean Pause Time
POS	Position
QUAD	Quadratic
QUAR	Quartic
QUIN	Quintic
SN	Subject Number
SD	Condition
(SD)	Standard Deviation
SS	Standard Score
VOCAB	Vocabulary

Age-Related Differences in Memory: The Role of the Executive

Psychologists have been interested in the nature and extent of age-related changes in memory for perhaps as long as they have been interested in memory itself. James (1890/1950) described memory impairment in older adults as resulting because "in old age forgetting prevails over acquisition (p.661)". During the first half of this century such introspective accounts of memory were largely abandoned due to the heavy influence of learning theory (e.g. Hull, 1943; Skinner, 1938; Tolman, 1932). These theorists described humans as passive organisms simply responding to environmental stimuli. Experiments were patterned largely after earlier research with animals; and with such a restricted theoretical basis, this early research added little that was fundamentally new to understanding the learning process in humans (Munn, 1954). Perhaps more importantly, it prevented the study of more mentalistic phenomena and, thereby, delayed more sophisticated investigation of age-related differences in memory.

The "cognitive revolution", which is generally acknowledged as beginning in 1958 (Craik, 1977), brought with it a renewed emphasis on investigation of the nature of mental life in man. By the 1970's, mainstream psychology had revised the long dominant behavioral theories with a new mentalist paradigm. The study of higher order cognitive properties in humans was now viewed not only as interesting, but also as necessary to adequately explain brain function and behavior (Sperry, 1988). This "paradigm shift" (Kuhn, 1970) set the stage for the rise of contemporary cognitive models of memory. Some of the initial attempts within cognitive psychology at developing comprehensive models of memory described it in terms of specific processing stages, which in turn had unique and identifiable characteristics (e.g. Atkinson & Shiffrin, 1968). Using such models as a basis, studies examining the nature of age-related changes in memory moved towards describing deficits in older adults in terms of specific stages of information processing.

Early Information Processing Models of Memory

Dividing memory into the three general stages of encoding (i.e. learning), storage, and retrieval, Eysenck (1974) hypothesized that encoding deficits in older adults were the basis of age-related differences in memory. This model was based upon findings that age differences in free recall were eliminated when older subjects were instructed to use mnemonic strategies during encoding. Another stage hypothesis (reviewed by Craik, 1977) proposed a retrieval stage deficit. This hypothesis cited evidence of greater age-related differences during free recall than recognition. Combining the methodology used in both these approaches, Till & Walsh (1980) demonstrated that age-related deficits could be demonstrated during either encoding, retrieval or both stages depending upon how a learning task is constructed. These authors then proposed a "double locus" hypothesis to explain these findings, and in so doing questioned whether stage models provided the most parsimonious way of explaining age-related deficits in memory. Due to findings such as these, more recent studies have acknowledged the need to move from univariate to more complex multivariate models to fully explain age differences in memory performance (Poon, 1985).

Age Differences in Attentional Resource

Stage models of memory have generally been abandoned, however, there remains an overall approach in the literature which attempts to differentiate specific components of cognition which decline with age from those that do not. One such approach which has been extensively cited in the literature is outlined by Hasher and Zacks (1979). These authors qualitatively distinguish between two types of processing based upon differences in attentional demands (Schneider & Shiffrin, 1977). Automatic processes are described as requiring little conscious control, and having minimal attentional demands. In contrast, effortful or, as they are sometimes called, controlled processes require active conscious intervention and are attentionally demanding. The authors explain that the less frequent use of a variety of learning strategies including imagery, rehearsal, organizational/clustering and mediational mnemonics by older adults is explained by age-related differences in attentional resources (Hasher, 1987; Zacks, Hasher, Doren, Hamm & Attig, 1987). Specifically, although individuals of all ages have a limited amount of mental resources available at a given moment, older adults have significantly more limited attentional resources. Thus, more effortful and more resource demanding cognitive activities would be expected to pose more of a challenge for older adults. Automatic processes, because of their minimal drain on capacity, are generally unaffected by decreased cognitive capacity and thus do not markedly change with age.

Working Memory

More recently Baddeley (1986) has proposed a model conceptually similar to effortful or controlled processing. Working memory is operationally defined as a short-term memory store in which information is being stored while this and/or other information is being actively processed. Moreover, working memory has been shown to be a capacity limited system in which performance on a particular task decreases in proportion to the degree to which capacity is taxed.

In an improvement of the two component model of Hasher and Zacks (1979), capacity limitations of working memory are measured directly using a secondary task procedure (Baddeley & Hitsch, 1974). The secondary task involves repeating digits, letters, or nonsense syllables at a constant rate.

In this technique, both the primary task (i.e. task of interest) and a secondary task are performed simultaneously. Given the assumption that working memory has a limited capacity, performance should deteriorate significantly on one task if a substantial amount of this capacity is taken up by another task. By giving subjects a large amount of practice, performance on the secondary task remains constant, and by increasing or decreasing the number of items which are rehearsed, the demands on capacity of the secondary task is varied systematically. At the same time performance on the primary task is left free to vary. By using the secondary task to control the amount of available working memory capacity, the capacity demands of the primary task can then be measured.

Utilizing this secondary task procedure, several studies have found older adults to have more limited working memory capacity. Specifically, as demands on working memory were increased, older adults displayed greater deficits in memory for discourse (Light & Anderson, 1985; Spilich, 1983) and verbal reasoning (Wright, 1981). Morris, Glick & Craik (1988) gave subjects a single sentence to verify as quickly as possible while concurrently rehearsing several unrelated words. Task effortfulness was manipulated by varying memory load (number of words rehearsed) and sentence complexity. By maintaining secondary task performance at ceiling level, interference of the primary task, measured by response latency and number of errors, was the variable of interest. Again, although older adults performed less well overall, only sentence complexity interacted with age. Thus, while passive rehearsal of words shows no age-related differences with increasing working memory capacity demands, age-related deficits in the more active processing which characterizes working memory was evident.

Executive Function

In addition to age differences in working memory capacity, Baddeley (1986) argues that many age differences in performance are due to limited capacity of a central executive system. Using Norman and Shallices' (1980) supervisory attentional system (SAS) as a basis, he describes the central executive as an overall controller used to override more automatic processes in response to changes in external factors. For example, the SAS would play an active role in a novel task in which using automatic types of processing alone, subjects would have difficulty. Instead, in such a task, input needs to be reorganized for successful performance. A critical feature of the executive which enables it to perform such functions is having sufficient capacity to develop and modify such strategies. Limitations in executive capacity should lead to predictable errors in performance.

An example of a task which is sensitive to capacity limitations in an executive system would be random generation of letters, (e.g. ABC, QRS). Obviously no set schema for such a task exists, and successful performance would seemingly require use of the executive to override automatic patterns of responding. Using such a task, Baddeley (1966) varied the rate at which subjects were to generate an item from two items/second to one item/four seconds. As rate (and thus the attentional demands of the task) was increased the percentage of stereotyped responses in output also increased.

In a second study which similarly examined random generation (Baddeley, 1966), subjects were required to sort regular playing cards into 1, 2, 4 or 8 categories. Again, this is obviously not a task for which there is a set schema. By keeping reaction time set at one item every two seconds, effortfulness was varied by increasing the number of sort categories. The percentage of stereotyped responses increased (and thus novelty decreased) with increasing number of sorting alternatives. Together, both studies suggest that as a random generation task becomes more capacity demanding, the number of automatic responses increases. More importantly for the current discussion, such results are consistent with a model of a capacity limited executive system.

More recent studies have yielded results which also seem to suggest that older adults have greater limitations on executive capacity. In one such study, Rabbitt (1982) tested reaction time in older adults while searching for the letters A B C D E F G and H in a visual display. In one condition subjects were asked to scan the list looking for any of these letters. In the second condition, subjects were asked to look for these same letters in sequence. While old and young performed comparably in the first condition, the performance of the older adults decreased significantly in the second condition. The comparable level of performance in the first condition suggests that the deficit is not simply one of strategy use or speed of processing. Under the sequential search condition a greater degree of planning is required, and the subject is asked to override automatic responses. The larger age difference in performance under these conditions thus would seemingly be consistent with a decrease in executive capacity.

Similar results to those outlined above have been found in studies examining age differences in intentional and incidental memory. Mitchell and Perlmutter (1986) found that old and young adults' performance was equal when tests of both recognition and recall were not expected (incidental). However, when either tests of recognition or recall were expected however, the younger adults out-performed the older subjects. Similarly, Light, Singh, and Capps (1986) found that age differences in memory performance were greater on a recognition measure described as a memory test than on a word completion measure which was not described as a memory test. This finding is particularly interesting because the recognition measure was described by the authors as less effortful. Thus, older subjects again show greater performance deficits when reorganization of input is required, as is the case during a test of memory. In contrast, during an incidental memory test subjects likely use more automatic schema which do not involve reorganizing input. Again, it appears to be the ability to reorganize input and override automatic schema which differs between young and older adults. Baddeley (1986) points out that such evidence lends at least indirect support to an executive capacity hypothesis of age differences in memory performance.

Glass and Holyoak (1986) have independently proposed that executive deficits form the basis of memory impairments consistently observed in older adults. Unlike Baddeley (1986), these authors propose that it is the flexibility of the executive to divide attention between multiple sensory inputs which is deficient. These authors do not, however, give an operational definition for their model of executive function and do not cite any direct evidence to support their position.

Theoretical discussions of the executive system as part of a model of human cognition began at the time cognitive psychology was emerging as a field of study. The first executive-like system was proposed in response to the perceived inadequacy of traditional behaviorally oriented explanations of human behavior (Chomsky, 1959), and the inability of these same approaches to fully account for individual variations in even simple activities (e.g. hammering a nail; Miller, Galanter & Pribram, 1960). The first formally named executive was outlined by Neisser (1967) who described it as performing functions including monitoring ongoing performance, and deciding whether to change or modify an ongoing strategy. This system and the many that have followed it have differed in their description and make-up, but are similar in that they all perform the role of executing specific learning strategies and controlling ongoing cognitive activity (e.g. Greeno & Bjork, 1973; Rabbit, 1982).

The prevalence of the executive in theory is not however reflected by a prevalence in research. Aside from case studies with brain injured patients (e.g., Heilman & Valenstein, 1985), executive function has been subjected to little direct experimental investigation. Because executive systems have been used to account for otherwise unexplainable variations in human behavior, it would naturally seem to be a difficult construct to measure experimentally. The resulting frustration of experimental psychologists is perhaps best summarized by Anderson and Bower (1973) who state "the executive is a particularly annoying source of complication in the analysis of memory experiments, for it determines the mnemonic strategies, heuristics and tricks that a subject may evoke to make his learning task easier" (p. 140). Thus, while the executive has been seemingly embraced theoretically by numerous authors as a means of explaining otherwise unaccountable differences in behavior, for perhaps the same reason, it has been approached only tentatively as the subject of empirical research.

Measurement of Executive Function

In an attempt to directly measure subject differences in executive function, Butterfield and Belmont (1977) proposed a specific operational definition, and an accompanying methodology to test this definition. These authors measured the time that subjects paused during each item in a series of sequentially presented items. By instructing subjects to use a specific recall strategy, they demonstrated that the resulting pause-time pattern (i.e. the plot of pause-time by position for each learning trial), reflected the use of this strategy (Belmont & Butterfield, 1977). For example, when subjects were instructed to recall the last three items of an eight item list first, a pause-time pattern was produced which showed a gradual increase in pause-time from item one to a peak at position five, followed by a sharp decrease for the last three items. Thus, this pattern reflected the specific recall instructions. By then changing the recall instructions to asking subjects to recall the last five items first, a corresponding change resulted in the pattern. Specifically, the peak moved from item five to position three with a sharp decrease for the last five items. Using this procedure, executive function was described as a change in a strategy or a series of strategies. This is reflected by a measurable change in pause-time pattern, occurring in response to a specific change in task demands, which in this case is experimenter instructions.

In addition to being related to recall instructions, pause-time patterns have also been demonstrated to be related to input strategy as measured by covert verbalizations (Butterfield, Siladi & Belmont, 1980). Subjects using a cumulative rehearsal strategy produced patterns which increased systematically from the first to the last item. In contrast, subjects using a grouping strategy in which groups of items are rehearsed together produced patterns with small peaks at points within the rehearsal set corresponding to the size of the groups being rehearsed (e.g. peaks at every third item would correspond to rehearsing items in groups of three). We have also demonstrated that young adults spontaneously generate different patterns which reflect the different structure of the lists being learned (Bergquist, Duke & Bray, 1988). Thus, pause-time pattern appears to reflect underlying cognitive activity. By measuring changes in cognitive activity directly, it also provides a means of quantifying executive function and, more specifically, executive flexibility.

Rigidity

Glass and Holyoak's (1986) relatively recent discussion of age-related differences in executive flexibility is not the first which has suggested that older adults are less flexible in their behavior. The study of inflexibility, or rigidity, as an identifiable phenomenon has existed for some time. This phenomenon has been studied extensively in a variety of clinical populations and age groups including older adults (e.g. Chown, 1959). Most of the interest has focused on differences in personality style. Factor analytic studies using a variety of personality and behavioral measures of rigidity have identified several types, including cognitive rigidity (Schaie, 1958; Shields, 1958). Although older adults have been shown to be more rigid on a variety of cognitive measures, there is disagreement as to whether rigidity has been confounded by age differences in intelligence (Chown, 1961).

The only study examining rigidity which directly measured ongoing cognitive activity in addition to performance was reported by Brinley (1965). In it, age differences in flexibility were compared to subjects' ability to shift from one function to another relative to their ability to perform comparable tasks not involving such shifts. The older subjects showed a larger decrease in performance going from the nonshift to the shift task. Several problems are apparent in this study. First, the author states that this effect was due to the greater difficulty of the shift task for older adults. Also there was no direct measure of flexibility, leaving uncertain the precise nature of age differences in cognitive rigidity. In summarizing the various problems inherent in this research, as well as suggesting the reason why this earlier concept of rigidity was abandoned as a topic of research, Botwinick (1978) states "The problem [of rigidity in later life] involves an ambiguity and a complexity that can be summarized only by recourse to extensive oversimplification" (p. 111). Although researchers have abandoned the study of rigidity as a global concept to explain a variety of cognitive, behavioral and personality changes, more recent studies have again investigated the flexibility of older adults by measuring change in cognitive activities across tasks.

Processing Flexibility

In a series of studies, Rabbit (1982) examined age differences in choice reaction time as a function of prior experience. In the first of these, young and old adults were asked to locate a series of target letters embedded within a visual display of letters. All subjects were first pre-trained using a fixed display in which the location of the target letters was allowed to vary, but the location of the surrounding letters remained constant. Following pretraining, subjects were asked to find the same target items, but with 50% of the displays the same as pretraining and thus familiar, and 50% new or unfamiliar. Both age groups were able to identify which visual displays appeared similar, and which appeared new. Despite this, on the familiar trials, younger subjects significantly improved their performance, while no such improvement was evident in older adults.

In a second study, young and older adults were given a three choice response task. The probability of occurrence of one signal differed from that of the other two (e.g. signals one, two and three had a 40%, 30% and 30% chance of occurring respectively). Younger subjects responded differentially based upon these differences in probability, while older subjects did not, even after 500 learning trials.

A third and final study required subjects to search displays of randomly arranged capital letters for specific targets. On the trials when these targets were present, they occurred next to specific background letters. These neighboring letters varied in their frequency with some always present when targets were shown, and some present only intermittently. Although the younger subjects located the target letters more rapidly when they occurred among frequent neighbors, the older adults did not. Again this happened despite older subjects being able to specify correctly which background letters most often occurred next to targets.

Combined, all three studies required subjects to perform activities for which there was not a set schema. The findings indicate that older adults appear deficient in developing search strategies despite recognizing relevant changes in the material they observed. These findings are unlike the results cited earlier by Baddeley (1966) in which increasing attentional demands resulted in a greater percentage of stereotyped responses. Instead, the changes in frequency of target stimuli did not appear to alter attentional demands. A more parsimonious explanation would appear to be that older adults are inflexible in modifying visual search strategies, even with extensive experience. This contrasts with younger adults who modify or even completely change their strategic behavior with practice.

Studies in age-related changes in problem solving ability have similarly found older adults to be inflexible at modifying or changing strategic behavior while performing a variety of tasks. Older adults have difficulty learning from past successes and failures, and appear to respond to each new problem independent of past performance (Reese & Rodeheaver, 1985). Hartley (1981) tested old and young adults in a concept problem task which involved establishing the relevance of various dimensions. The task was self-paced and described by the authors as requiring a low memory load. The older adults did not improve their performance despite identifying the critical information in the problem. In a subsequent study Hartley and Anderson (1983) found that older subjects did not modify problem solving strategies as task demands changed, again in spite of being able to identify these changes.

Examining age differences in hypothesis testing, Offenbach (1974) found older subjects to be impaired in correct use of multidimensional cues to test various hypotheses. Specifically, the errors made by older adults indicated an inability to shift from one type of cue to another, and occurred despite pretraining on all cues.

Overall, their performance was significantly worse than young adults and adolescents, and comparable to a group of second graders. This task is very similar in design to the Wisconsin Card Sort Test (Heaton, 1981), a neuropsychological measure which is reported to measure executive function (Lezak, 1983). It should therefore come as no surprise that older adults have been shown to be impaired on this instrument as well (Haaland, Vranes, Goodwin & Garry, 1987). Thus, similar to what was noted previously, older adults appear inflexible and unable to change their ongoing processing based upon recent feedback or changing task demands. A plausible explanation of these results is that older adults have difficulty modifying a strategy in response to an identifiable change in an information processing task, an explanation which is similar to the definition of executive flexibility outlined by Butterfield & Belmont (1977).

Two Process Model of Executive Function

The studies reviewed thus far seemingly give support for age-related deficits in executive function. These deficits take the form of either limited flexibility or limited executive capacity with age. Instead of representing two different explanations of the executive and the basis of its limitations, these may both be important components of an overall executive system which becomes increasingly limited with age.

Pause-time pattern has been used to directly measure executive flexibility by demonstrating specific changes in patterns which reflected specific changes in recall instructions, as described earlier (Belmont & Butterfield, 1977). The literature however provides no methodology to measure directly executive capacity. The secondary task procedure (Baddeley & Hitsch, 1974) has been used to demonstrate limitations in working memory capacity using measures such as mean pause time. Baddeley (1986) cites numerous studies which are interpreted as indicating that the executive system is capacity limited and that there is an age difference in this capacity limitation. Unlike studies of working memory, no single procedure is outlined for examining capacity demands on the executive. Using the same secondary task procedure in combination with a measure of executive function would seemingly offer a means to do just this. Specifically, by using pause-time patterns instead of mean pause-time as a dependent measure, this procedure would offer a means of quantifying the capacity demands of changes in strategic behavior in response to identifiable changes in information processing tasks. By definition, this then will provide a means of measuring executive capacity.

Hypotheses

The purpose of this study was to investigate age-related differences in executive function and delineate more specifically than has been done in previous research, which aspects of this executive system change with age. The central executive is defined as an overall controller used to override more automatic processes in response to changes in task demands. Two critical characteristics of the executive which limit its ability to perform this function are limitations in capacity and flexibility. A system very critical to this discussion is working memory. In order to ensure that differences in executive function are accurately measured, working memory capacity must be separated from executive capacity

In contrast to the growing literature on age-related differences in working memory (see Baddeley, 1986 for a review), there has been little attempt to investigate directly age-related differences in executive function. However, executive deficits have been proposed as the basis of some performance deficits consistently observed in older adults (Baddeley, 1986; Glass & Holyoak, 1986). Given a two-process model of executive function which includes limitations in capacity and flexibility, there is question as to which of these is the basis of age-related deficits. By using a combination of measures which have been demonstrated in previous research to quantify differences in flexibility and capacity, this study attempted to investigate age-related differences in working memory capacity, executive capacity, and executive flexibility.

Specifically, young and old adults learned categorized picture lists (primary task) while simultaneously repeating 0, 2 or 4 digits (secondary task). All subjects learned four lists of 12 pictures each, and were given three trials to learn each list, creating a total of twelve trials. Exposure time (pause-time) for each picture was determined by the subject, who advanced through the list at his or her own pace. The lists differed in their structural characteristics with half the lists being composed of two categorized groups, while the other half was composed of three categorized groups. A modification of the procedure described by Butterfield and Belmont (1977) was used. Instead of being instructed in a specific recall strategy (e.g. recalling the last three items of an eight item list first), subjects were instructed to recall pictures from one of either two or three categories following each trial. In this way subjects were encouraged to attend to differing structural characteristics of the two lists and produce two learning strategies as shown by two different pause-time patterns. The resulting three dependent measures were percent recall for each trial, mean pause-time for each trial, and the twelve point pause-time pattern created for each trial.

As described earlier, working memory is defined as performing operations involving storage and manipulation of information simultaneously. Both of these operations compete for limited attentional capacity. By having subjects perform two attentionaly demanding tasks simultaneously, in this case list learning and digit repetition, and systematically increasing the attentional demands of the digit span (secondary) task, any resulting decreases in performance in the list learning task reflect limitations in working memory. Further, interactions of differences in learning tasks with digit load, which reflected a greater effect of increasing attentional demands in the secondary task on one type of task versus others, indicate that this task demands more working memory capacity. Similarly, interactions of load with age which reflect a greater effect of increasing digit load on one age group versus the other indicates that this age group has more limited working memory capacity. This interpretation is consistent with previous research using this same procedure (Baddeley, 1986).

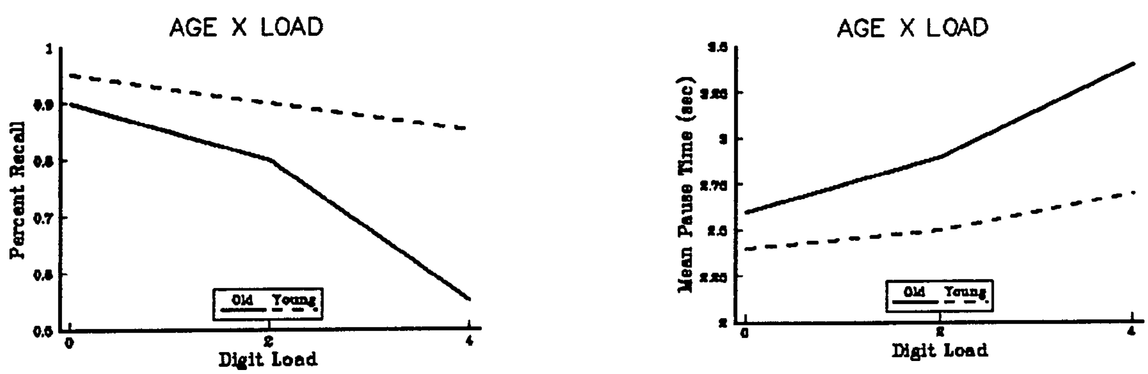
Using the modified pause-time procedure described above, changes in pause-time pattern in response to changes in the organization of to-be learned material (i.e. learning two versus three group lists) were taken as a measure of executive flexibility. Specifically, spontaneous changes in the distribution of pause-time across serial positions, or as it is also referred to, pause-time pattern, which corresponded to changes in the organization of the to-be-learned material were taken to measure executive flexibility.

By using the secondary task procedure (a measure of capacity) in combination with pause-time measurement (a measure of executive flexibility), capacity limitations of the executive were measured in much the same way as capacity limitations for working memory. The critical difference was that instead of the effect of load, the two-way load x position interaction served as the basis for examining limitations in executive capacity. This then provided a direct measure of the effects of executive capacity limitations on executive flexibility. Flexibility changes not affected by increasing demands on capacity (i.e. position effects but no load x position effects), were interpreted as reflecting differences in executive flexibility, independent of limitations in executive capacity. Follow-up analyses were conducted to describe the nature of any differences in capacity or flexibility with age.

Thus, if working memory capacity decreases with age, it is predicted that older adults will display increasing mean pause time and decreasing recall with increasing digit load compared with younger adults, without any higher order interactions involving pause-time (see Figure 1).

If executive capacity decreases with age, it is predicted that older adults will display decreasing recall, but no differences in mean pause time compared with younger adults. In addition, it is predicted that pause-time pattern will change with increasing digit load in older adults for each of the list structures, while there will be little or no comparable changes in younger adults (see Figure 2).

Last, if executive flexibility decreases with age, it is predicted that older adults will display a relatively greater performance deficit in the alternating condition compared with the same condition, without any interactions of age and digit load. In addition, it is predicted that older adults will produce different pause-time patterns for the alternating and same conditions, for each of the two list structures (see Figure 3).



NO POSITION X AGE X CONDITION X LIST STRUCTURE INTERACTION

NO POSITION X AGE X LOAD X LIST STRUCTURE INTERACTION

Figure 1: Prediction 1: Age Differences in Working Memory Capacity

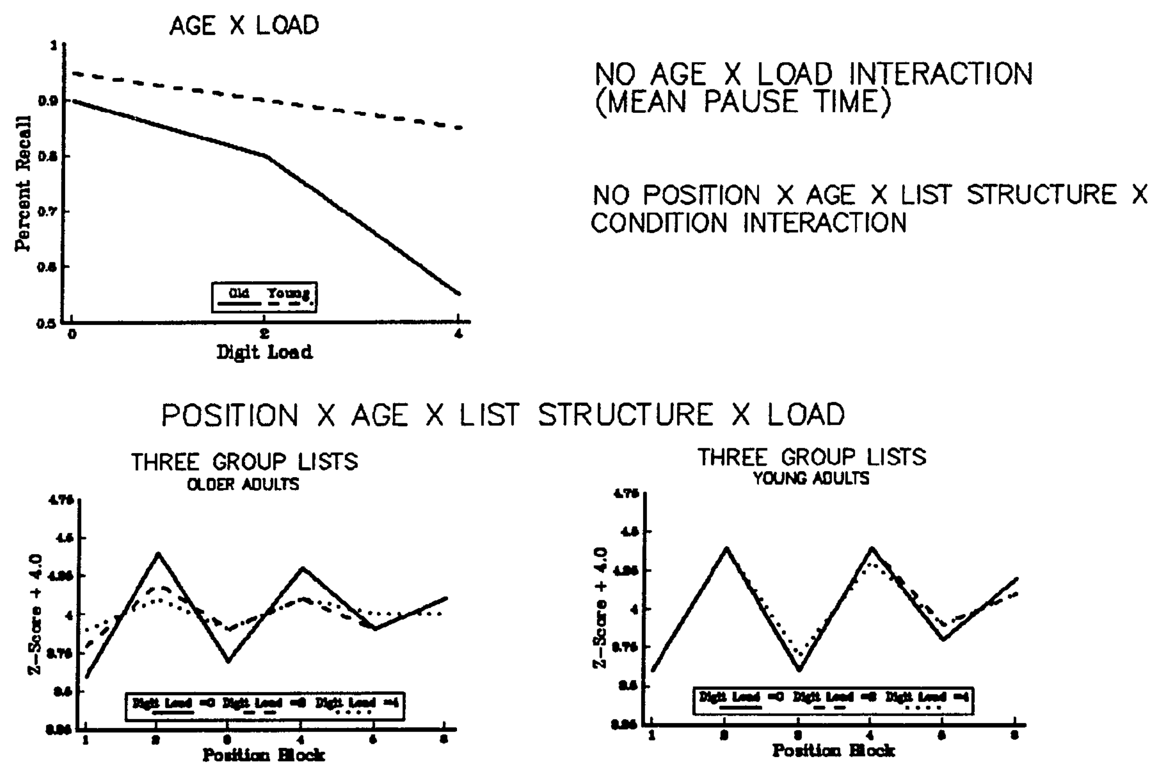
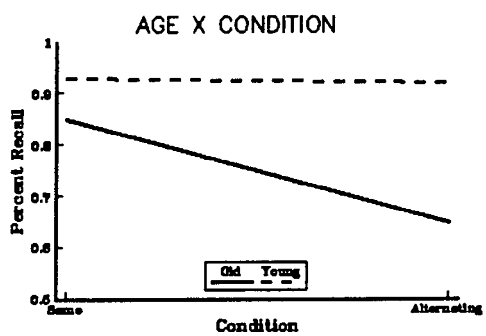


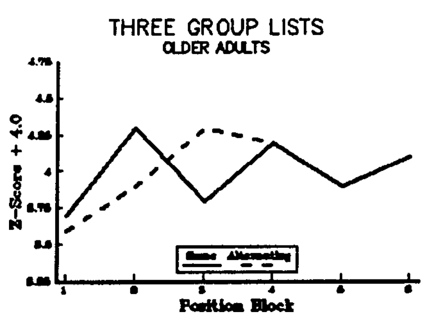
Figure 2: Prediction 2: Age Differences in Executive Capacity



NO AGE X LOAD INTERACTION
(MEAN PAUSE TIME)

NO POSITION X AGE X LIST STRUCTURE X
LOAD INTERACTION

POSITION X AGE X LIST STRUCTURE X CONDITION



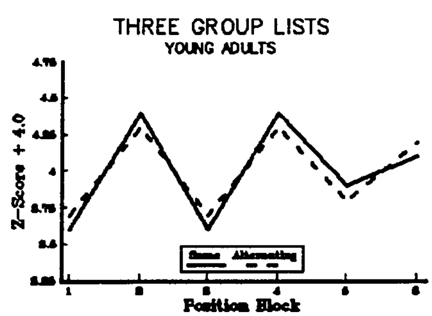


Figure 3: Prediction 3: Age Differences in Executive
Flexibility

Methods

Subjects

A total of 48 subjects, 24 each in an older and younger group participated in this study, with the restrictions that educational level and sex ratio were approximately equal. Subjects who had uncorrected vision, evidence of cognitive impairment as measured by a mental status exam, or significant health problems as measured by a health screening questionnaire were excluded. The mean age of older subjects was 67.7 years (range = 62 - 80); the mean number of grades completed was 14.4 (range = 8 - 18). Younger subjects averaged 22.3 years of age (range = 18 - 27), and 13.08 years of education (range = 12 - 15). This represents a significant difference in years of education between age groups $F(1,46) = 14.78$, $p < .01$. Young and old age groups had an equal ratio of males to females with both having 10 males and 14 females. The vocabulary subtest of the Wechsler Adult Intelligence Scale - Revised (WAIS-R) was administered to both young and old subjects as a measure of estimated verbal intelligence. Older subjects averaged a raw score of 56, and a scaled score (Mean = 10.0, standard deviation = 3.0) of 12.91, while younger subjects averaged a raw score of 45.82 and a scaled score of 11.17. This also represented a significant difference between age groups, $F(1,46) = 12.74$, $p < .01$.

Older subjects were all active, and community dwelling; all were recruited through church groups and senior citizens' activity centers in the Birmingham area. To measure the current physical health of older subjects, each was administered a health screening questionnaire. This asked each older adult to indicate whether he or she had suffered from any of 25 classes of illnesses during the previous month (See Appendix I). Each subject was also asked to rate the impact of each of these illnesses on his or her life on a 4 point Likert-Type scale. This scale ranged from one, no impact to four, significant impact. Older subjects rated themselves as having 3.66 illnesses on average, and rated these illnesses as having an average impact of 1.67 (no impact to mild impact) on their life. Older subjects were also asked to indicate if they were currently taking any one of 18 classes of medication (See Appendix II). Overall, older subjects averaged taking 2.58 medications.

Younger subjects were solicited through the University of Alabama at Birmingham Department of Psychology subject pool, and given extra credit towards their grade in psychology courses for their participation. All subjects were fully informed of the experimental nature and purpose of the study prior to participating.

Table 1

Subject Characteristics

			Older Adults			
Variable:	AGE	ED	VOCAB SS	ILLNESS	MEDS	IMPACT
Mean (SD)	67.70 (5.43)	14.35 (2.03)	12.91 (2.70)	3.66 (2.51)	2.58 (2.46)	1.67 (0.753)
			Younger Adults			
Variable:	AGE	ED	VOCAB SS			
Mean (SD)	20.45 (2.92)	12.58 (0.97)	11.17 (2.44)			

Materials

Primary Task

All subjects learned a series of four, twelve-item picture lists and were given three trials to learn each list. Each list contained line-drawings from five semantically based categories (e.g. clothing, animals). All pictures were pretested on young and old subjects to ensure that they were readily recognizable. Each list had items ordered in a blocked fashion such that items from the same category were presented in sequence. Pictures were presented on an Apple IIe computer with the rate of presentation determined by each subject.

Two types of list structures were created. In the first type, there were two categories containing six items each. Thus, the first six items were in one category and the last six items, in a second (6-6). The second list type contained three categories with the first four items in one category, the next four items in a second category and the last four in a third (4-4-4). In each age group, subjects were randomly assigned to either a same or alternating condition, which differed in the order in which lists were presented. In the alternating condition, subjects were presented lists in an alternating order. Thus in this condition there were three shifts from one list structure to another (Between lists one and two, two and three, and three and four). In the same condition subjects were presented only one type of list (e.g. all three group lists). Half of all subjects in the alternating condition began with a three group list while the other half began with a two group list. In the same condition subjects were randomly assigned all three group lists or all two group lists. The positions of category blocks within lists, as well as items within categories, were randomized between subjects to control for any order effects.

Secondary Task

To measure the amount of processing capacity each of these tasks required, a secondary task procedure was used (Baddeley & Hitsch, 1974). In this task subjects rehearsed several digits aloud beginning prior to each learning trial and recalled all digits following the same recall trial. On each trial, subjects rehearsed zero, two or four numbers corresponding to low, moderate and high capacity load conditions respectively. The number of digits rehearsed was randomized across each of the three trials for each list, with the restriction that within each subject, each length digit series was rehearsed, once across the three trials of each list.

Design

This study used a five-way 2 x 2 x 2 x 4 x 3 mixed partially nested factorial design. The between group factors included age (young and old), condition (same versus alternating), and, partially nested under the same condition, list structure (two group versus three group), The within group factors included list (one through four), secondary task load (zero, two or four digits), and list structure, partially nested under alternating condition.

Procedure

Each subject was tested individually. Prior to beginning the procedure, subjects were administered the vocabulary subtest of the WAIS-R. In addition, older subjects were asked to complete a health screening questionnaire and medication questionnaire.

Subjects were initially instructed that they would be presented with four lists of pictures on the computer screen, one picture at a time, each of which was twelve items in length. They were told that by pressing the space bar on the keyboard they could go through the list at their own pace. They were further instructed that each list would have the pictures grouped based upon category membership (e.g. animals, clothes, etc.). The number of groups in each list varied and might be the same as in the preceding list or might be different. Following each learning trial, they were told that they would be asked to recall as many items as possible in a specific category. To demonstrate this, each subject was given two practice lists of pictures, with items similar to those in the actual experimental lists. One of these lists had two categories of six items each, and the other had three categories of four items each. Subjects were asked to name each item aloud, and then to name as many items as they could remember in a particular category. This served both to ensure that they understood the overall procedure of the task, and to emphasize in particular the group structure of the lists. It also was used to ensure that the subjects could adequately see the pictures and accurately name them. Subjects who did not understand this following a single trial on both practice lists repeated the procedure. Subjects were then told that of the four lists that they would be receiving, all four might be of a structure similar to the two group list, all might be of a similar structure to the three group list, or the four might alternate between the two types of lists.

Prior to beginning the actual list learning task, but following the instruction with the two practice lists, subjects were then instructed in concurrent task performance. They were told that while pacing themselves through the pictures, they would be rehearsing numbers overtly at a fixed rate (one rehearsal every two to four seconds). The experimenter initially modeled this for the subject, and the subject then practiced this task a sufficient number of times so that performance was error free. Each was told that he or she would be asked to rehearse either two or four digits, and that on some trials they would not rehearse any digits. While learning the pictures, subjects were prompted to continue rehearsing overtly at a constant rate. The secondary task was started at a variable time in advance of the primary task (between five to fifteen seconds). In this way performance was kept constant on the secondary or concurrent task, while measures of primary task performance were allowed to vary (Baddeley & Hitsch, 1974; Morris, Gick, Craik, 1988).

Subjects did not know how many digits they would be asked to rehearse prior to each trial. On each new trial in which digit rehearsal was required, a new set of digits was given.

Following the completion of the first trial of each list, subjects were asked the number of categories in that list. This was done as a means of ensuring that each subject accurately noted the structural characteristics of the list. After each of the twelve trials, subjects were asked to recall as many items as they could, in any order, from a specific category on the list.

Results

Percent recall, mean pause time, and pause time pattern were the three principal dependent measures, each of which was analyzed separately. All effects which are reported to be significant, are at the $p < .05$ level. Using the entire data set, the list structure factor was partially crossed with list. Specifically, for subjects in the alternating condition, list structure was used as both a within group factor and a between group factor (every subject received two, three group lists and two, two group lists in a counterbalanced order). It represented only a between group factor however, in the same condition (each subject received four, three group lists, or four, two group lists). To balance the design, only data from lists two and four were used in the final analyses. With this modification, subjects in both the same and alternating groups received either two, three group lists, or two, two group lists. The resulting analysis was a 2 x 2 x 2 x (2 x 3) mixed factorial design. The between group factors included age (young and old), condition (same versus alternating list structure), and list structure (two group versus three group), The within group factors included list (two and four), and secondary task load (zero, two or four digits). The difference between subjects in the alternating and same conditions was that in the same condition, the two lists were immediately preceded by lists of a similar structure, while in the alternating group they were preceded by lists of the different structure.

Recall

Recall was measured as the percentage of pictures recalled correctly, with a possible range of 0.00 to 1.00. The main effect of age was significant, $F(1,40) = 14.69$, while the main effects of condition, list structure, list, and load were all nonsignificant ($Fs < 1.0$). The significant main effect of age reflected superior performance by the younger subjects who recalled a mean of 0.912 compared to a mean of 0.823 for older subjects. The nonsignificant effects of condition and list structure indicate that neither the number of groups in each list, nor whether subjects received the same or alternating lists affected overall recall. Also, the nonsignificant effects of load and list reflect that overall recall performance did not change significantly over successive lists, and was not affected by concurrent task load.

The two-way interaction of list structure x list was significant, $F(1,40) = 10.43$, while no other two-way interactions were significant. The simple main effects of list for the three group lists was significant, $F(1,20) = 8.285$, but nonsignificant for the two group lists, $F(1,20) = 3.150$. The first of these reflected a decrease in recall from list 2 to list 4 for the three group list, while the second reflected little change in recall across lists for the two group lists (See Table 2).

The three-way interaction of age x list structure x list, $F(1,40) = 12.67$ was significant, while all other three-way interactions, as well as other higher order interactions, were nonsignificant. Examining the significant three-way interaction leads to a better understanding of the list structure x list interaction (See Figure 4). The simple age x list interactions for the three, $F(1,20) = 7.34$, and two group lists, $F(1,20) = 5.59$ were significant. The simple main effect of list for older adults in the three group lists, $F(1,20) = 9.11$, was significant, but nonsignificant for young adults in the three group lists, $F < 1.0$. For the two group lists, the simple main effect of list was similarly significant for list older adults, $F(1,20) = 4.64$, and nonsignificant for young adults, $F(1,20) = 1.18$. Together these results showed that in older adults there is a practice effect over successive two group lists, but interference over successive three group lists.

Mean Pause Time

Mean pause time was the mean time subjects paused for each picture, on each trial in seconds. The main effect of digit load was significant, $F(2,80) = 9.27$, while the main effect of age, $F(1,10) = 1.54$, as well as the main effects of condition, list structure, and list ($Fs < 1.0$) were nonsignificant. The significant main effect of load

Table 2

Percent Recall Means and Standard Deviations for List Structure X List Interaction

List Structure	List	Recall
Three Group	2	0.910 (0.175)
	4	0.789 (0.314)
Two Group	2	0.805 (0.262)
	4	0.888 (0.183)

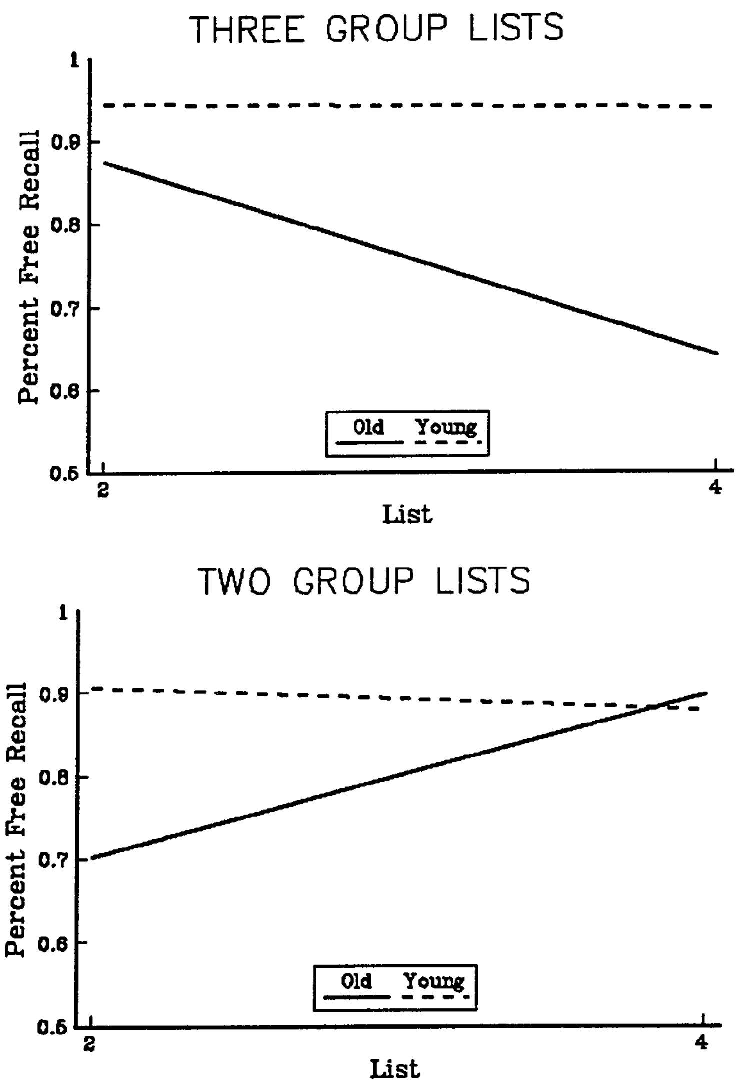


Figure 4: Percent Recall Means for the Age X List Structure X List Interaction

reflected that subjects spent increasingly greater time learning the pictures as secondary task load, and thus the demands on working memory capacity was increased. Overall, subjects paused an average of 2.416 seconds under the zero digit condition, 2.853 seconds under the two digit condition, and 3.225 seconds under the four digit condition. Nonsignificant efects of age and list structure indicate that the two age groups spent a comparable amount of time learning pictures, that subjects studied two and three group lists for a comparable amount of time, and that subjects spent an equivalent amount of time studying lists in the same and alternating conditions.

No two-way interactions were significant. The three-way interaction of condition x list x load, $F(2,80) = 3.68$, was significant (See Figure 5), while no higher order interactions were significant. Examining each of the simple two-way condition x load interactions for list 2 and 4, significant results were obtained for list 2, $F(2,80) = 6.24$, but nonsignificant for list 4, $F < 1.0$. The simple main effect of load was examined for list 2, in each of the conditions. While the simple main effect of load for the list 2 in the same condition was nonsignificant, it was significant for list 2 in the alternating condition, $F(2,40) = 15.39$. This would seemingly suggest that during early learning trials of the alternating condition, in which subjects were given successive lists of differing structure, a greater amount of working memory capacity was required

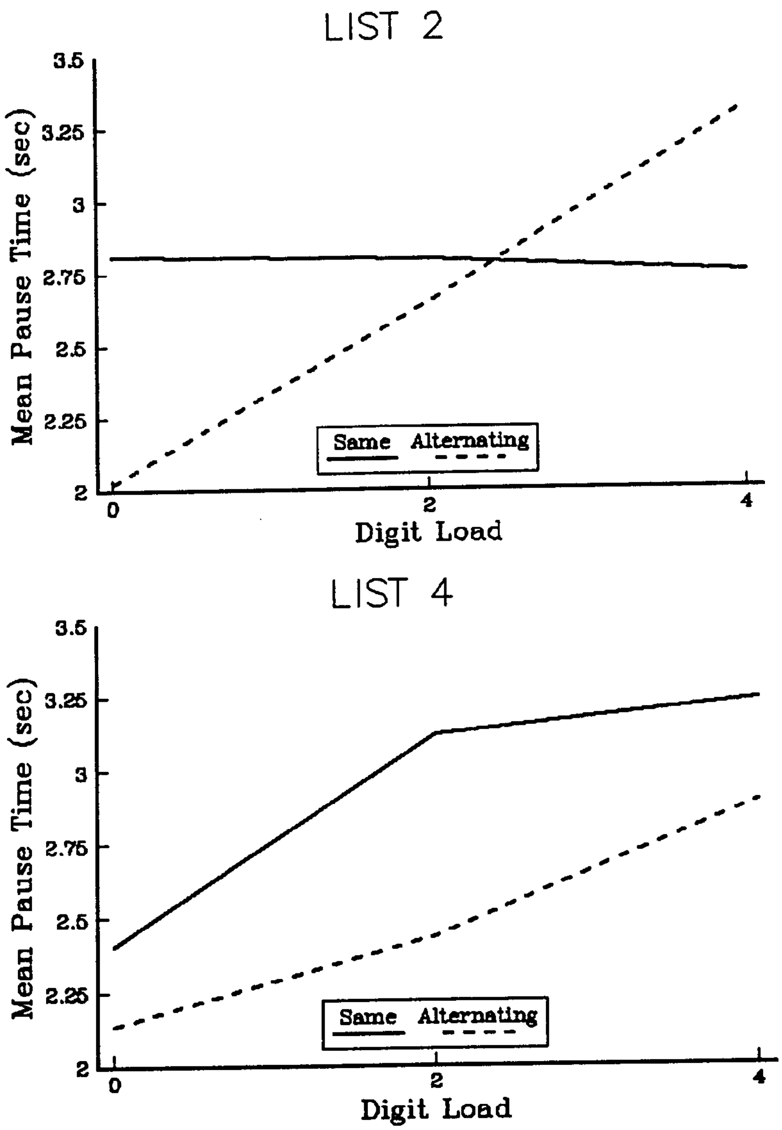


Figure 5: Mean Pause Times for the Condition X List X Load Interaction

than when subjects were given lists of the same structure. The lack of an absolute difference in mean pause time between the same and alternating conditions however complicates such an interpretation. This difference between conditions was not evident at list 4, and in fact there is a noticeable, if nonsignificant, $F < 1.0$, difference in mean pause time between the same and alternating conditions such that subjects spent more time learning the same lists. Again, although nonsignificant, the greater time required to learn the same lists is inconsistent with an interpretation that the alternating condition places greater demands on working memory capacity. The lack of any interactions involving age and load indicates that unlike previous studies, the procedure used here did not reveal age-related differences in working memory capacity.

Pause-Time

Pause-time was the amount of time which subjects paused to examine each of the twelve pictures in each list. This created a twelve point pause-time pattern which will be referred to simply as a pattern. Because previous research has demonstrated that patterns with greater mean study times have greater variability across positions (Belmont, Feretti & Mitchell, 1977), standardized pause times were obtained for each trial. This was done by using the mean and standard deviation for each trial to calculate standardized pause times with a mean of 4.00 and standard deviation of 1.00. Using pause-time patttern as a dependent measure, the main effect of position (differences in pause time across positions one to twelve) was examined, as well as the interaction of position with other within group and between group factors. In a previous study this measure was similarly used and several differences were identified between age groups (Bergquist, Duke & Bray, 1987). The main effect of position was significant, $F(11,440) = 9.29$, reflecting a variation of pause-time across positions.

Follow-up trend analyses were done with higher order interactions involving position to examine the specific differences contributing to these interactions. To produce more readily interpretable patterns, as well as more conservative estimates of trend in patterns, adjacent positions were averaged on the full 12 point patterns (e.g. 1 and 2, 11 and 12), creating a 6 point collapsed pattern of six serial position blocks. The results of trend analyses and any follow-up contrast analyses were performed on these serial position blocks. In these new patterns the category breaks were preserved: between blocks 2 and 3, and 4 and 5 for the three group lists, and between blocks 3 and 4 for the two group lists.

Significant two-way interactions included position x age, $F(11,440) = 2.72$, and position x list structure, $F(11,440) = 1.96$. The position x age interaction reflected differing patterns of pause-time for the two different age groups. The significant position x list structure interaction reflects differing pause-time patterns for the

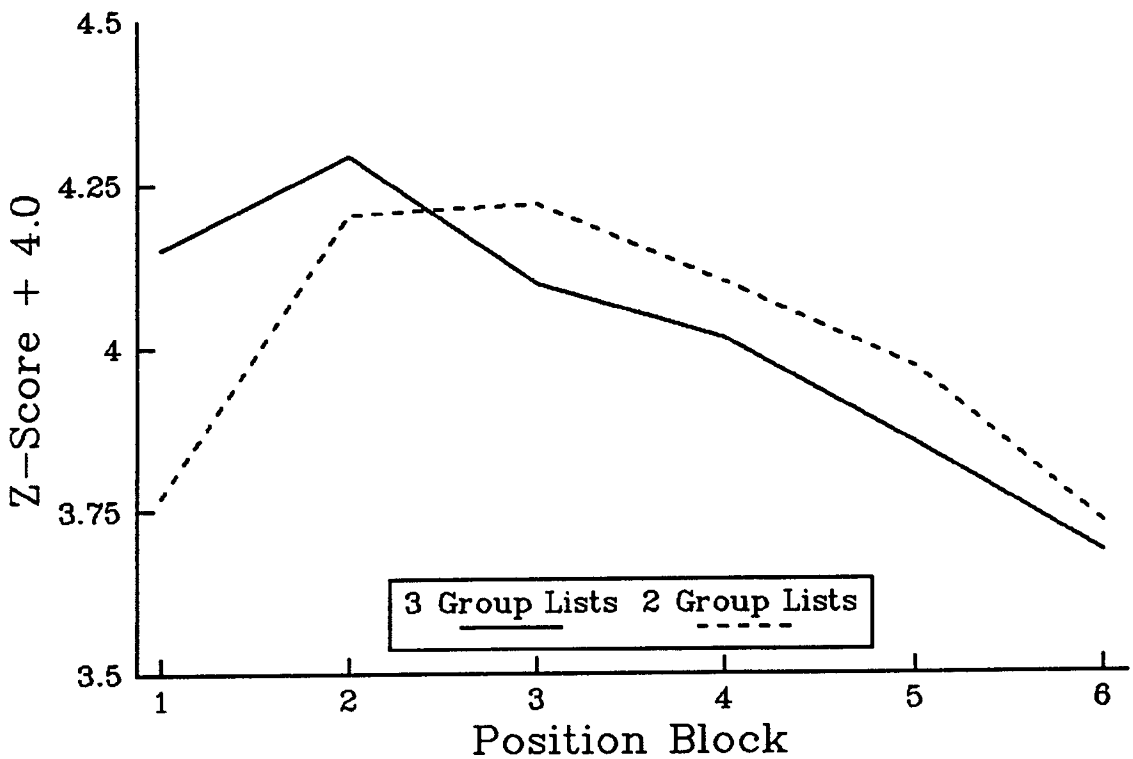


Figure 6: Pause-Time Patterns for the Position X List Structure Interaction

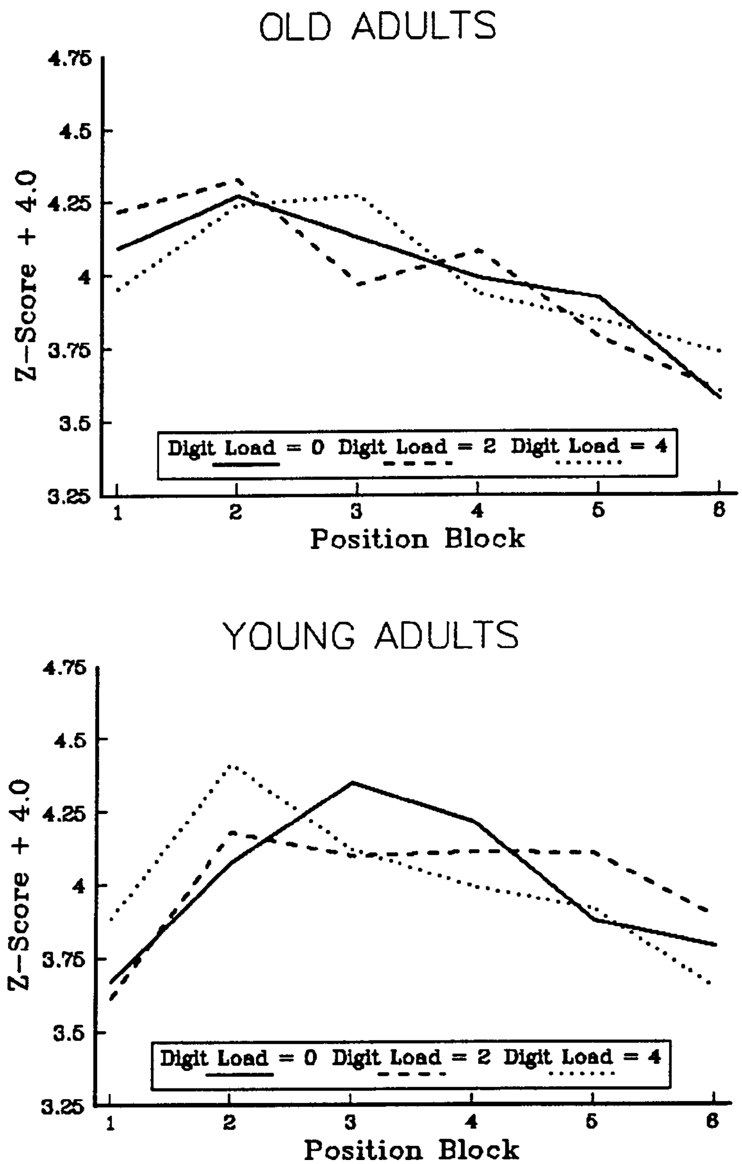


Figure 7: Pause-Time Patterns for the Position X Age X Load Interaction

two differing list structures and is given in Figure 6. Consistent with this interaction, trend analyses revealed two different patterns for the two list structures. The full pattern for the three group list had a significant quartic trend, $F(1,20) = 7.81$, while the full two group list pattern had a significant quadratic trend, $F(1,20) = 32.18$. The plot of this interaction is given in Figure 6. All remaining trend analyses were performed on collapsed six position block patterns.

The single significant three-way interaction was position x age x load, $F(22,880) = 1.81$. This interaction reflects a difference in how younger and older subjects distributed their pause-time over increasing load conditions. The simple position x load interaction for the younger subjects was significant, $F(22,440) = 1.96$, while it was nonsignificant for the older subjects, $F < 1$. This three-way interaction is given in Figure 7. Younger subjects appeared to be altering their pause-time pattern under conditions of differing capacity demands, while the older subjects were not. The lack of any interaction with list structure however precludes any meaningful interpretation of this interaction.

One last significant interaction was the four-way interaction of position x age x condition x list structure, $F(11,440) = 1.97$, which is given in Figure 8. No other higher order interactions were significant. Looking at the same and alternating conditions, the simple position x age x

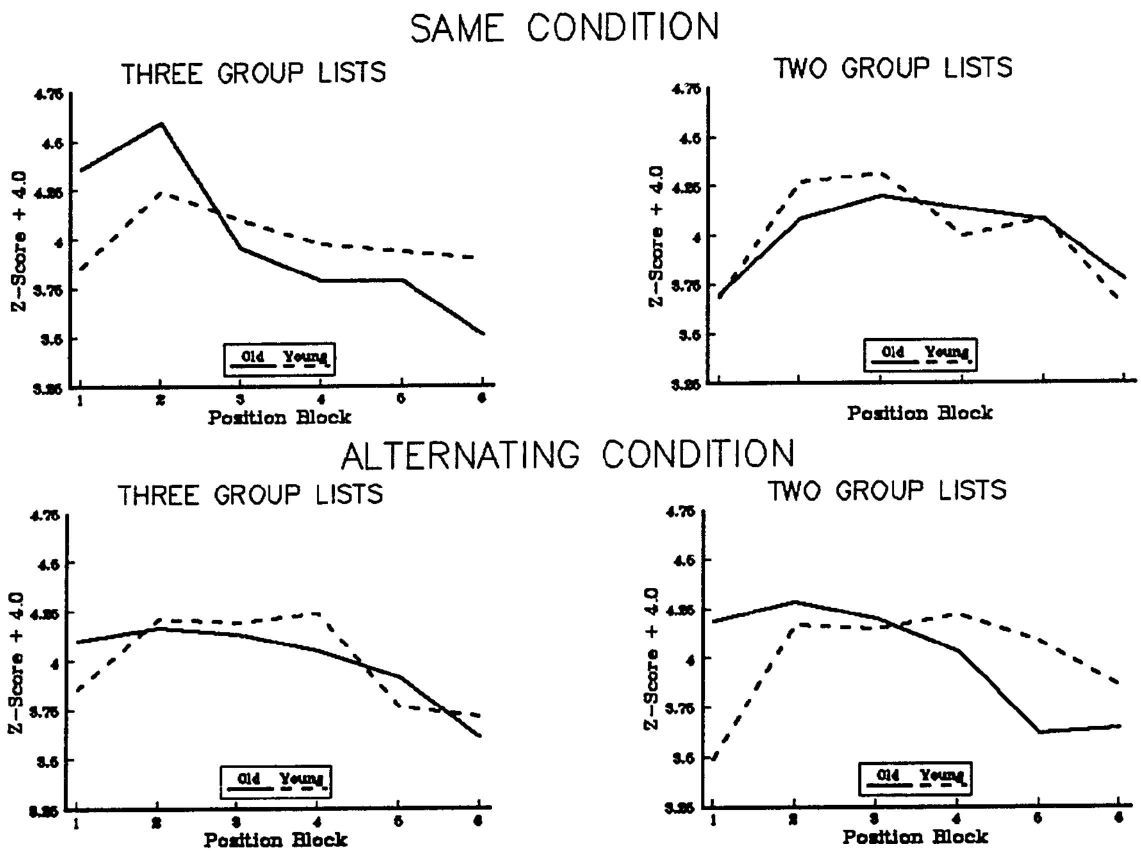


Figure 8: Pause-Time Patterns for the Position X Age X Condition X List Structure Interaction

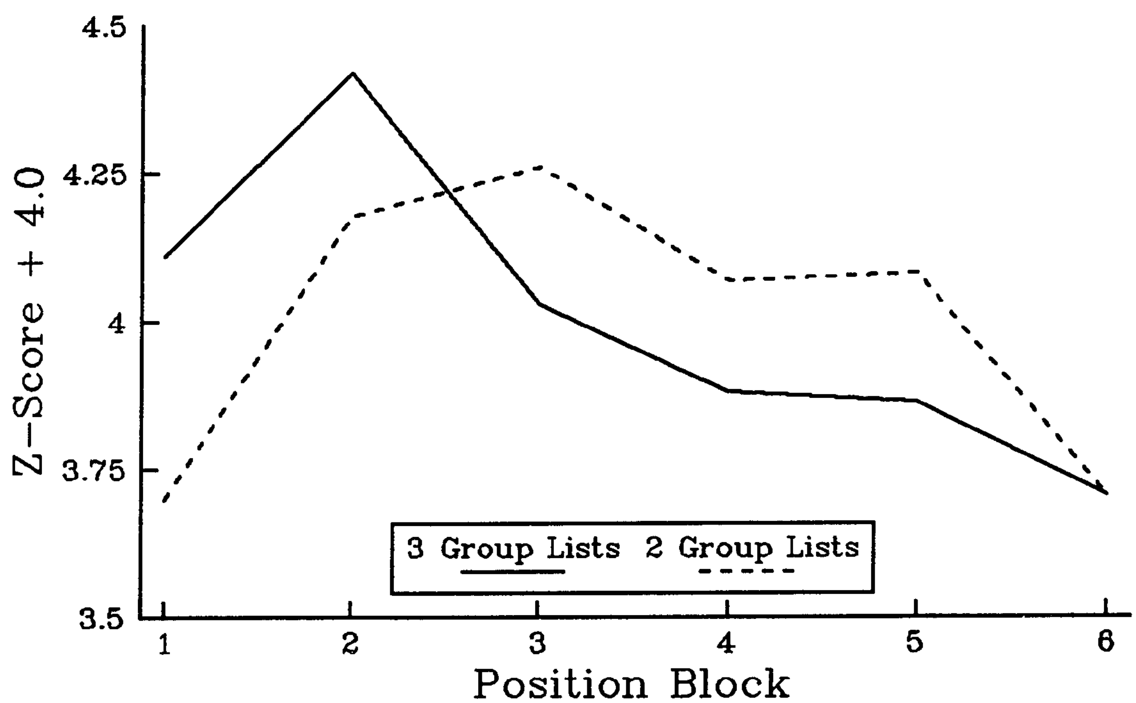


Figure 9: Pause-Time Patterns for the Position X List Structure Interaction in the Same Condition

list structure interaction was nonsignificant for the same condition, F(11,220) = 1.21, but significant, for the alternating condition, F(11,220) = 2.23.

The nonsignificant simple three-way interaction for the same condition and the significant simple position x list structure interaction for the same condition, F(11, 220) = 2.260, indicate that subjects produced statistically different pause-time patterns for the two and three group lists, as shown in Figure 9. Trend analyses for each of these patterns also revealed differences, with a significant quartic trend
for the three group lists, F(1,10) = 17.33, and a significant quadratic trend for the the two group list, F(1,10) = 18.65. These trends reflected the two differing structures of the lists with the three group lists which have two category breaks having a two peak quartic pattern, and the two group lists which have a single category break, having a single peak quadratic trend.

Analysis of the simple position x age x list structure interaction, under the alternating condition was significant, F(11,220) = 2.230. The simple position x age interactions in the alternating condition were examined for each of the two and three group lists. These were nonsignificant for the three group lists, F < 1.0 (Figure 8, bottom left), and significant for the two group lists, F(11,110) = 4.36 (Figure 8, bottom right). Thus when learning the three group lists older and younger subjects

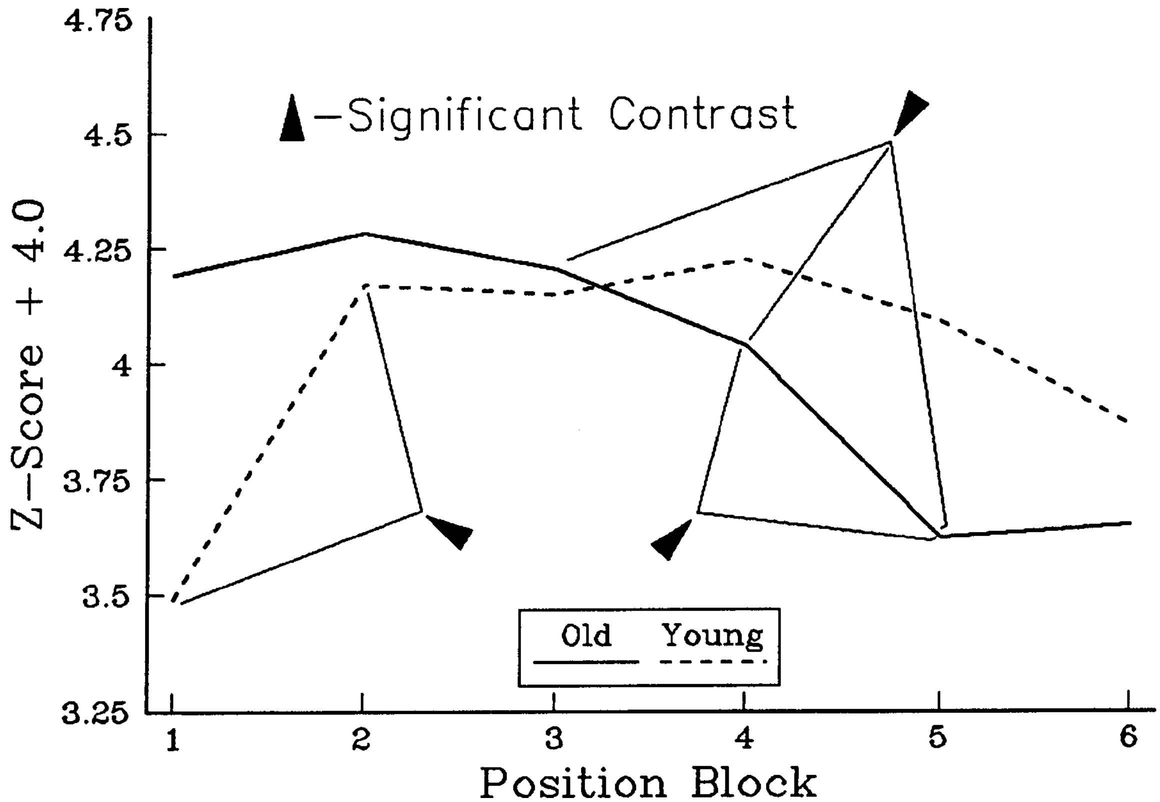


Figure 10: Pause-Time Patterns for the Age X Position Interaction in the Alternating - Two Group List Condition

generated statistically comparable patterns. Averaging across age groups the resulting pattern had a significant quadratic trend, $F(1,10) = 14.40$. Thus when learning three group lists which were preceded by two group lists, older and younger subjects generated a quadratic pattern, which differed from the quartic pattern in the same condition.

The significant simple position x age interaction for the alternating-two group condition reflects that the two age groups generated differing pause-time patterns. Looking at each of these individually (see Figure 10), the pattern for the older subjects represented a decreasing linear trend, $F(1,5) = 10.36$, while the younger subjects produced a quadratic pattern, $F(1,5) = 21.89$. Contrast analyses (see Figure 10) of specific points reveal that for the older adults, the contrast of blocks 4 and 5 was significant, $F(1,5) = 11.21$, as was the contrast between block 4 and the combination of blocks 3 and 5, $F(1,5) = 14.67$. For the younger subjects, the contrast between blocks 1 and 2 was significant, $F(1,5) = 7.86$.

Overall these results support an age difference in learning when alternating between two and three group lists. While old and young subjects did not differ when given lists of similar structure to learn, the two age groups did differ when learning alternating two and three group lists. Specifically, while old and young subjects produced statistically comparable patterns for three group lists preceded by two group lists, their patterns differed when learning two group lists preceded by three group lists, with the younger subjects producing a quadratic trend pattern, and older adults producing a decreasing linear trend pattern.

Discussion

Consistent with the majority of the published literature in aging and memory (see Craik, 1977 for review), this study found age differences in free recall memory performance. An age effect was also seen in the three-way interaction of age x list structure x list. This interaction was initially difficult to explain and was not predicted. It reflected an increase in recall for older adults learning the two group lists, compared with decreasing performance over trials for older adults learning three group lists. Given the lack of an interaction with load, these results do not directly support the conclusion that the three group lists placed greater demands on the processing capacity of the older adults. The larger number of groups in these lists, however, may have resulted in greater interference from previously learned material, even without placing greater demands on capacity. Hulicka (1967) found that, given a comparable number of learning trials, interference effects were greater for older adults. This interference was due to the effects of prior learning, rather than due to increasing attentional demands during task performance. The lack of an interaction involving load might have been due to greater inter-category interference for the older subjects even though such differential interference effects were not expected.

The significant main effect of load while measuring mean pause-time indicates that the secondary task procedure outlined by Baddeley and Hitsch (1974) was a viable means of increasing the load on working memory capacity. The significant condition x load x list interaction (See Figure 5), which reflected greater attentional demands of the alternating condition during early learning trials, seemingly suggests that learning successive lists which alternated in their structural characteristics (i.e. alternating between two group lists and three group lists) demanded more capacity than learning lists having the same structural characteristics (i.e. lists which were either all two groups or all three groups).

One possibly confusing element in the interpretation of the results is the lack of any absolute difference in mean pause time between the same and alternating conditions at list 2, despite the differing effects of digit load on mean pause time between these conditions. Also, the greater mean pause time at list 4 for the same condition compared with the alternating condition is contrary to the interpretation that the alternating condition places greater demands on capacity. Specifically, while the effect of increasing digit load was greater on subjects learning alternating lists, subjects in this condition did not require more time overall than those learning four lists of a similar structure. If, however, the alternating condition places greater demands on working memory capacity, then it would seem reasonable to expect that there would be an overall difference in the amount of time needed to learn these lists compared to learning the four lists of a similar structure. Also, if the alternating condition is more attentionaly demanding, then why under the zero digit load condition (see Figure 1) at list 2, did subjects actually spend less time learning lists in the alternating condition than in the less demanding same condition? This seemingly would argue that under these circumstances the alternating condition was actually less demanding on capacity. Thus while the pattern of increasing mean pause-time with increasing digit load in the alternating condition is consistent with an interpretation that this condition places greater demands on working memory capacity, the lack of an absolute difference in the means qualifies any conclusions in this area. Besides adding some confusion to the results obtained in this study, the finding here of no absolute difference in mean pause time, despite differential effects of the secondary task procedure, raises more general questions about accurate interpretation of results from working memory studies which the authors of this procedure did not address (Baddeley, 1986; Baddeley & Hitsch, 1974).

The lack of any interaction of these factors with age suggests the possibility that greater capacity demands in the alternating condition, at least during early learning trials, did not differentially impact the working memory of older and younger adults. The significantly greater absolute mean pause time for older adults in both lists 2 and 4 of the alternating condition does suggest that older adults may have found this condition more effortful. It is not however amenable to an interpretation of age differences in working memory capacity and, moreover, inconsistent with previous literature which has found age-related differences in working memory capacity (Baddeley, 1986). Thus while the secondary task procedure was sensitive to differences in capacity demands of the same and alternating conditions, it did not identify any age differences in working memory capacity.

In addition to attempting to replicate previous research which has identified age-related limitations in working memory capacity, this study also attempted to measure age-related differences in executive system capacity. This was done by combining a measure of executive flexibility (pause-time) with capacity (secondary task procedure). The significant position x age x load interaction which, when broken down by age groups, reflected a significant simple position x load interaction for the younger adults, with the comparable interaction being nonsignificant for older adults. This suggests possible executive capacity limitations for younger, but not older adults. As seen in Figure 7, the younger adults change from creating a nearly symmetrical pattern under the zero digit condition with a peak at serial position block 3, to a decreasing linear pattern with a peak at serial position block 2 in the four digit condition. The lack of any interaction with either list structure or condition, however, precludes any meaningful interpretation of this change in pause-time patterns with increasing digit load, and consequently prevents any interpretations regarding limited executive capacity.

Age differences were identified in pause-time pattern which possibly point towards age-related limitations in executive flexibility. Specifically, in the same condition, old and young adults performed comparably, producing different pause-time patterns for the two group lists and the three group lists. When learning four three group lists, subjects produced a pause-time pattern with a quartic trend, while when learning four two group lists subjects produced a pattern with a quadratic trend. Examination of the two patterns in Figure 6 shows that the highest point in the three group pattern is at the break between the first and second four item groups (between serial position block 2 and 3, while the highest point in the two group pattern is at break between the two six item categories (between serial position block 3 and 4). These two patterns at least partially reflect the two list structures to which they correspond. Thus when given a series of similar lists, subjects generated patterns which trend analyses indicate show some correspondence to the structural characteristics of the lists being learned.

In the alternating condition where subjects learned lists which were preceded by lists of different structural characteristics, old and younger subjects differed depending on the type of list. When learning three group lists which were immediately preceded by two group lists, the two age groups again did not differ significantly, and generated a pattern which shows less correspondence to the three group lists than is seen in the same condition. Specifically, this pattern contains a less pronounced decline at the category break between serial position blocks 2 and 3 than the three group pattern in Figure 9.

The two age groups did differ in the alternating condition when learning two group lists which were proceeded by three group lists (see Figure 10). While the younger subjects generated a quadratic pattern under these conditions, the older adults produced a decreasing linear pattern. Examining the pattern for the two group lists produced by the younger adults in Figure 8, the highest point is at serial position block 4 which immediately follows the category break. The results of contrast analyses however indicate that while block 4 is the highest point in the pattern, it does not differ significantly from the position blocks which immediately precede and follow (position blocks 3 and 5). The pattern for the two group lists produced by older subjects in this same figure has its highest point at serial position block 2 with contrast analyses indicating a significant decrease in pause-time following the category break at serial position block 3.

The pattern generated by the younger subjects described above displays some relationship to the structure of the two group lists to which it corresponds, although it is arguably a weak one at best. The pattern generated by the older subjects however has little to no relationship to the corresponding two group list structure. A possible explanation for this decreasing linear pattern produced by older adults is offered from the results of our previous work. Given that older subjects were able to generate patterns in the same condition when learning the three and two group lists which showed at least some similarity to the structural characteristics with which they corresponded, the linear pattern in the alternating condition may have represented a transitional pattern, which was intermediate between the two peak and single peak patterns. In an earlier study (Bergquist, Duke & Bray, 1987), subjects generated linear patterns when given an ungrouped, and thus unstructured list. A linear pattern may thus also represent an individuals' response to conditions of changing structure. Given a greater number of trials, the older subjects may have generated a pattern matching the structural characteristics of the to-be-learned material. Thus older subjects may be displaying a relatively greater degree of inflexibility in learning strategies than younger subjects when alternating between two differently structured lists.

This possible age difference in flexibility in the absence of any findings indicating age-related differences in executive or working memory capacity limitations suggest that the age differences in flexibility may be observed independent of capacity demands in either system. This would be consistent with Glass & Holyoak's (1987) position that older adults display age-related deficits in executives' ability to flexibly distribute limited attentional resources. This lack of flexibility by older adults however was not associated with a corresponding pattern of age-related differences in performance. Specifically, although a significant age effect for recall reflected that younger adults performed better than older adults overall, there was not an interaction of age x condition x list structure which would have corresponded to the significant four-way interaction involving pause-time. Thus although there is some evidence to support, albeit tentatively, age-related differences in executive flexibility, these are not associated with age-related differences in performance.

Obviously to give more weight to any argument for age-related differences in executive flexibility, further research is necessary. In particular, several shortcomings of this study suggest possible directions for future studies. First, the small number of lists used here limited subjects' ability to change pause-time pattern in a way that would have been evident with greater time and practice. In particular, the age differences noted in pause-time in the two-group lists between the same and alternating conditions may have been different if a larger number of lists were used. In other words it might be that older subjects are able to produce a pattern which matches the structural characteristics of the to-be-learned material if only given a sufficient number of trials. Also using only 12 item lists, and only two list structures (two or three groups), naturally limited the findings and conclusions of this study. It would be very interesting to test the differential effects on pause-time pattern contributions to increasing both the size of groups in the lists, as well as the number of groups themselves. Seemingly these may have differential effects on capacity and flexibility. Previous studies have found that while increasing the amount of material to be learned did not result in greater age differences in working memory capacity, increasing the complexity of the to-be-learned material (e.g. number of groups) did. Seemingly by altering both the size and complexity of the lists to be learned, a more comprehensive picture of both capacity and flexibility limitations may be revealed.

Other factors which may have limited the findings include the inclusion of the two practice lists prior to beginning the actual experimental procedure. Although this allowed subjects to learn the specific experimental procedure prior to learning the actual list items, it at the same time may have eliminated greater differences in performance which were present during early learning trials. This is supported by a previous study in which practice lists were not used, and in which age differences in pause-time pattern were found almost exclusively on the first learning trial of each of four lists. In addition while asking subjects to recall a specific group of pictures within each list, subjects were not required to recall these items in any order. This may also have limited the power of the procedure, as previous studies yielding significant results used ordered recall.

In their discussions of the use of pause-time as a measure of executive function, Belmont and Butterfield (1977) advocate using an instructional approach as a means of gaining better control on variability in individual subjects' behavior. In an important difference from the method used in this study, these authors' instructed subjects in two or more specific retrieval strategies, and then measured the ability of subjects to change from one set of instructions to the next. The change in pause-time pattern in response to differing retrieval instructions was taken as demonstrating executive function. This type of a procedure offers greater experimental control, and possibly by using it more highly significant, and readily interpretable results would have been obtained. It can be argued however, that such a strict methodology also eliminates many of the important aspects of executive function as defined by Baddeley (1986) and others (e.g. Glass & Holyoak, 1987) by not allowing individuals to respond spontaneously to changes in their environment. Seemingly, executive function by its very nature will likely always prove difficult to measure, and perhaps just as difficult to define. Moreover, it will also provide a challenging trade-off between developing workable methodologies and adhering to relevant theories, and models of cognitive functioning.

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APPENDIX I

HEALTH SCREENING QUESTIONNAIRE

Name____________________ Date____________

Current and Recent Health Problems

Listed below are a number of health problems. Please indicate which of these health problems, if any, that you currently have or have had in the last month by circling the word Yes. For those health problems that you have not had in the last month, circle No. If your answer is Yes, please circle a number to indicate how much that particular health problem has interfered with your activities. Use the following scale:

1 = no effect
2 = slight effect
3 = moderate effect
4 = strong effect

Health Problem	Occur in Your Life During Last Month ?		If yes, effect of problem			
1. Arthritis or rheumatism	Yes	No	1	2	3	4
2. Other pain in muscles or joints such as back problems or muscle cramps.	Yes	No	1	2	3	4
3. Colds, flu, sore throat, or other respiratory infections.	Yes	No	1	2	3	4
4. Asthma	Yes	No	1	2	3	4

Current and Recent Health Problems
(Continued)

Health Problems Effect	Occur in Your Life During Last Month		If Yes, of Problem			
5. Emphysema or chronic bronchitis	Yes	No	1	2	3	4
6. Headaches	Yes	No	1	2	3	4
7. Heart problems	Yes	No	1	2	3	4
8. High Blood Pressure	Yes	No	1	2	3	4
9. Anemia	Yes	No	1	2	3	4
10. Other circulation problems	Yes	No	1	2	3	4
11. Diabetes	Yes	No	1	2	3	4
12. Stomach or intestinal disorders such as stomach aches, indigestion, or ulcers	Yes	No	1	2	3	4
13. Gall Bladder problems	Yes	No	1	2	3	4
14. Liver disease	Yes	No	1	2	3	4
15. Kidney disease	Yes	No	1	2	3	4
16. Other urinary tract disorders such as urinary tract infections yeast infections, or prostate problems	Yes	No	1	2	3	4
17. Skin problems such as rashes, warts, or sores	Yes	No	1	2	3	4
18. Glaucoma	Yes	No	1	2	3	4
19. Cancer or leukemia	Yes	No	1	2	3	4
20. Thyroid disorders	Yes	No	1	2	3	4

Current and Recent Health Problems
(Continued)

Health Problems	Occur in Your Life During Last Month		If Yes, Effect of Problem			
21. Nervous system disorders such as stroke, Parkinson's disease, or Alzheimer's disease	Yes	No	1	2	3	4
22. Dizziness, shakiness, or vision	Yes	No	1	2	3	4
23. Problems speaking or understanding speech	Yes	No	1	2	3	4

<u>Please indicate any other health problems you have experienced over the past month. Briefly describe these problems and rate their effects.</u>

24.______________________________ 1 2 3 4

25.______________________________ 1 2 3 4

APPENDIX II

MEDICATION QUESTIONNAIRE

Listed below are a number of medications. Please indicate which of these medications you are taking or have taken in the past month by circling Yes or No.

Medication	Taking now or in the past month?	
1. Prescription pain killers	Yes	No
2. Non-prescription pain killers such as aspirin		
3. High blood pressure medicine	Yes	No
4. Digitalis,nitroglycerine, or other medicines for your heart or for chest pain	Yes	No
	Yes	No
5. Blood thinner medicine (anticoagulants).		
6. Medicine to make you lose water or salt		
7. Insulin for Diabetes	Yes	No
8. Other medicine for diabetes	Yes	No
9. Prescription ulcer medicine	Yes	No
10. Antibiotics	Yes	No
11. Cold medicine such as decongestants	Yes	No

Medication Questionnaire
(Continued)

Medication	Taking now or in the past month?	
12. Allergy medicines such as antihistamines	Yes	No
13. Hormone supplements such as steroids or estrogen	Yes	No
14. Thyroid medications	Yes	No
15. Diet pills	Yes	No
16. Sleeping pills	Yes	No
17. Seizure medications such a Dilantin	Yes	No
18. Tranquilizers, antidepressants, or other medications for your nerves or emotional states	Yes	No

Please list any other medications you are taking.

19.______________________________

20.______________________________

APPENDIX III

INSTRUCTIONS

In this study I will ask you to do two tasks simultaneously:

1) The first of these will be to learn a series of four picture lists, each containing 12 pictures (subject shown both sets of samples, asking he/she to name each picture in the list). The list will have items grouped together in categories, such that items from a given category will be grouped together in the list.

For Example: In the first example, the first four items are sports items, while the next four are tools, and the last four are types of furniture. In the second example, the first six items are types of clothing, while the last six items are types of transportation.

Some of the four lists may have three groups of four items, just as the first example which you received, while others may have two groups of six items like the second example. The four lists which you receive may be either type of list, or a combination of both. I want you to note the categories in each list because following each learning trial I will ask you for one group in the list.

For Example: In the first example I may ask you for the first group of items in which case I would want you to give me as many items as you can remember in that group. (Ask subject to name them). In the second list I may ask you you for as many items as you can remember in the second group (Ask subject to name them).

2) In addition to learning the picture lists, I will also be asking you to rehearse some numbers aloud. I want you to do this while you are learning the pictures. I will ask you to either rehearse two numbers, four numbers, or no numbers.

For Example: Say the numbers 7-1-9-2 and repeat them once every 2-4 seconds. (Subject does this for at least 10 seconds, or longer if necessary).

Instructions
(Continued)

To see each new picture all you have to do is to press the space bar. Following the last picture you will hear three loud beeps from the computer and the screen will go blank.

At that time I will ask you to recall all of the items that you can in a particular group. Remember every list will have either two or three groups of items.

APPENDIX IV
ANALYSIS OF VARIANCE
RECALL

SOURCE	DF	ANOVA SS	ANOVA MS	F VALUE
AGE	1	1.369	1.369	14.69*
SD	1	0.029	0.029	< 1.0
AGE*SD	1	0.006	0.006	< 1.0
AB	1	0.000	0.000	< 1.0
AGE*AB	1	0.145	0.145	1.564
SD*AB	1	0.007	0.007	< 1.0
AGE*SD*AB	1	0.223	0.223	< 1.0
SN(AGE SD AB)	40	3.727	0.093	
L	1	0.024	0.024	< 1.0
AGE*L	1	0.000	0.000	< 1.0
SD*L	1	0.070	0.070	< 1.0
AGE*SD*L	1	0.125	0.125	1.74
AB*L	1	0.750	0.750	10.43*
AGE*AB*L	1	0.911	0.911	12.67*
SD*AB*L	1	0.346	0.346	< 1.0
AGE*SD*AB*D	1	0.075	0.075	1.04
L*SN(AGE SD AB))	40	2.876	0.071	
D	2	0.031	0.015	< 1.0
AGE*D	2	0.044	0.022	< 1.0
SD*D	2	0.015	0.007	< 1.0
AGE*SD*D	2	0.074	0.037	< 1.0
AB*D	2	0.011	0.005	< 1.0
AGE*AB*D	2	0.031	0.015	< 1.0
SD*AB*D	2	0.066	0.033	< 1.0
AGE*SD*AB*D	2	0.029	0.014	< 1.0
D*SN(AGE SD AB)	80	3.579	0.044	< 1.0

* - $p < .05$

ANALYSIS OF VARIANCE
RECALL

L*D	2	0.024	0.012	< 1.0
AGE*L*D	2	0.064	0.032	< 1.0
SD*L*D	2	0.016	0.008	< 1.0
AGE*SD*L*D	2	0.013	0.006	< 1.0
AB*L*D	2	0.023	0.011	< 1.0
AGE*AB*L*D	2	0.046	0.023	< 1.0
SD*AB*L*D	2	0.004	0.002	< 1.0
AGE*SD*AB*L*D	2	0.015	0.007	< 1.0
L*D*SN(AGE SD AB)	80	2.748	0.034	

* - $\underline{p} < .05$

APPENDIX V

ANALYSIS OF VARIANCE
RECALL
THREE GROUP LISTS

SOURCE	DF	ANOVA SS	ANOVA MS	F VALUE
AGE	1	1.204	1.204	11.92*
SD	1	0.032	0.032	< 1.0
AGE*SD	1	0.077	0.077	< 1.0
SN(AGE SD AB)	20	2.037	0.101	
L	1	0.522	0.522	8.29*
AGE*	1	0.463	0.463	7.35*
SD*L	1	0.101	0.101	1.60
AGE*SD*L	1	0.197	0.197	3.13
L*SN(AGE SD AB)	20	1.270	0.635	
D	2	0.020	0.010	< 1.0
AGE*D	2	0.0	0.0	< 1.0
SD*D	2	0.047	0.047	< 1.0
AGE*SD*D	2	0.089	0.044	< 1.0
D*SN(AGE SD AB)	40	1.933	0.048	
L*D	2	0.005	0.003	< 1.0
AGE*L*D	2	0.102	0.063	< 1.0
SD*L*D	2	0.001	0.0	< 1.0
AGE*SD*L*D	2	0.003	0.001	< 1.0
L*D*SN(AGE SD AB)	40	1.576	0.039	

* - $\underline{p} < .05$

APPENDIX VI

ANALYSIS OF VARIANCE
RECALL
TWO GROUP LISTS

SOURCE	DF	ANOVA SS	ANOVA MS	F VALUE
AGE	1	0.310	0.310	3.69
SD	1	0.003	0.003	< 1.0
AGE*SD	1	0.152	0.152	1.81
SN(AGE SD AB)	20	1.689	0.084	
L	1	0.252	0.252	3.15
AGE*L	1	0.447	0.447	5.59*
SD*L	1	0.003	0.003	< 1.0
AGE*SD*L	1	0.003	0.003	< 1.0
L*SN(AGE SD AB)	20	1.606	0.080	
D	2	0.022	0.011	< 1.0
AGE*D	2	0.074	0.037	< 1.0
SD*D	2	0.034	0.017	< 1.0
AGE*SD*D	2	0.014	0.007	< 1.0
D*SN(AGE SD AB)	40	1.646	0.041	
L*D	2	0.042	0.021	< 1.0
AGE*L*D	2	0.008	0.004	< 1.0
SD*L*D	2	0.018	0.009	< 1.0
AGE*SD*L*D	2	0.025	0.012	< 1.0
L*D*SN(AGE SD AB)	40	1.172	0.029	

* - $p < .05$

APPENDIX VII

ANALYSIS OF VARIANCE
RECALL

THREE GROUP LISTS
OLDER ADULTS

SOURCE	DF	ANOVA SS	ANOVA MS	F VALUE
SD	1	0.004	0.004	< 1.0
SN(AGE SD AB)	10	1.945	0.194	
L	1	0.984	0.984	9.11*
SD*L	1	0.291	0.291	2.69*
L*SN(AGE SD AB)	10	1.080	0.108	
D	2	0.009	0.005	< 1.0
SD*D	2	0.124	0.062	< 1.0
D*SN(AGE SD AB)	20	1.436	0.071	
L*D	2	0.054	0.027	< 1.0
SD*L*D	2	0.000	0.000	< 1.0
L*D*SN(AGE SD AB)	20	1.364	0.068	

* - $p < .05$

ANALYSIS OF VARIANCE
RECALL

THREE GROUP LISTS
YOUNGER ADULTS

SOURCE	DF	ANOVA SS	ANOVA MS	F VALUE
SD	1	0.105	0.105	11.67*
SN(AGE SD AB)	10	0.092	0.009	
L	1	0.000	0.000	< 1.0
SD*L	1	0.008	0.008	< 1.0
L*SN(AGE SD AB)	10	0.189	0.018	
D	2	0.121	0.006	< 1.0
SD*D	2	0.012	0.006	< 1.0
D*SN(AGE SD AB)	20	0.496	0.024	
L*D	2	0.053	0.026	2.60
SD*L*D	2	0.005	0.002	< 1.0
L*D*SN(AGE SD AB)	20	0.221	0.010	

* - $p < .05$

APPENDIX VIII

ANALYSIS OF VARIANCE
RECALL

TWO GROUP LISTS
OLDER ADULTS

SOURCE	DF	ANOVA SS	ANOVA MS	F VALUE
SD	1	0.102	0.102	< 1.0
SN(AGE SD AB)	10	1.433	0.143	
L	1	0.686	0.686	4.64*
SD*L	1	0.006	0.006	< 1.0
L*SN(AGE SD AB)	10	1.489	0.148	
D	2	0.058	0.029	< 1.0
SD*D	2	0.005	0.003	< 1.0
D*SN(AGE SD AB)	20	1.218	0.060	
L*D	2	0.030	0.015	< 1.0
SD*L*D	2	0.024	0.012	< 1.0
L*D*SN(AGE SD AB)	20	0.820	0.041	

* - $p < .05$

ANALYSIS OF VARIANCE
RECALL

TWO GROUP LISTS
YOUNGER ADULTS

SD	1	0.054	0.054	2.16
SN(AGE SD AB)	10	0.256	0.025	
L	1	0.013	0.013	1.18
SD*L	1	0.000	0.000	< 1.0
L*SN(AGE SD AB)	10	0.116	0.011	
D	2	0.038	0.019	< 1.0
SD*D	2	0.043	0.021	< 1.0
D*SN(AGE SD AB)	20	0.427	0.021	
L*D	2	0.020	0.010	< 1.0
SD*L*D	2	0.020	0.010	< 1.0
L*D*SN(AGE SD AB)	20	0.351	0.017	

* - $p < .05$

APPENDIX IX

ANALYSIS OF VARIANCE
MEAN PAUSE TIME

SOURCE	DF	ANOVA SS	ANOVA MS	F VALUE
AGE	1	23.56	23.56	1.538
SD	1	6.11	6.11	< 1.0
AGE*SD	1	2.52	2.52	< 1.0
AB	1	1.27	1.27	< 1.0
AGE*AB	1	4.73	4.73	< 1.0
SD*AB	1	0.05	0.05	< 1.0
AGE*SD*AB	1	20.51	20.51	
SN(AGE SD AB)	40	612.73	15.318	
L	1	0.02	0.02	< 1.0
AGE*L	1	0.03	0.03	< 1.0
SD*L	1	1.48	1.48	< 1.0
AGE*SD*L	1	0.33	0.33	< 1.0
AB*L	1	2.10	2.10	< 1.0
AGE*AB*L	1	0.06	0.06	< 1.0
SD*AB*L	1	0.0	0.0	< 1.0
AGE*SD*AB*D	1	0.02	0.02	< 1.0
L*SN(AGE SD AB)	40	14.05	0.35	
D	2	24.12	12.06	9.28*
AGE*D	2	3.300	1.65	1.27
SD*D	2	5.95	2.98	2.29
AGE*SD*D	2	2.24	1.12	< 1.0
AB*D	2	1.04	0.52	< 1.0
AGE*AB*D	2	2.40	1.20	< 1.0
SD*AB*D	2	1.19	0.59	< 1.0
AGE*SD*AB*D	2	2.04	2.04	< 1.0
D*SN(AGE SD AB)	80	104.03	1.30	

* - p <.05

ANALYSIS OF VARIANCE
MEAN PAUSE TIME

L*D	2	0.59	0.29	< 1.0
AGE*L*D	2	0.79	0.39	< 1.0
SD*L*D	2	6.78	3.39	3.68*
AGE*SD*L*D	2	2.96	1.48	1.64
AB*L*D	2	2.18	1.09	1.48
AGE*AB*L*D	2	3.31	1.65	1.79
SD*AB*L*D	2	4.77	2.38	2.59
AGE*SD*AB*L*D	2	2.26	1.13	1.23
L*D*SN(AGE SD AB)	80	73.50	0.92	

* - $\underline{p}$ <.05

APPENDIX X

ANALYSIS OF VARIANCE
MEAN PAUSE TIME
LIST 2

SOURCE	DF	ANOVA SS	ANOVA MS	F VALUE
AGE	1	10.967	10.967	1.34
SD	1	0.786	0.786	< 1.0
AGE*SD	1	2.346	2.346	< 1.0
SN(AGE SD AB)	40	327.735	8.193	
AB	1	0.530	0.530	< 1.0
AGE*AB	1	2.952	2.952	< 1.0
SD*AB	1	0.027	0.027	< 1.0
AGE*SD*AB	1	9.558	9.558	1.17
SN(AGE SD AB)	40	327.735	8.193	
D	2	9.189	4.594	4.95*
AGE*D	2	3.555	1.777	1.91
SD*D	2	11.575	5.787	6.24*
AB*D	2	1.223	0.611	< 1.0
AGE*SD*D	2	0.050	0.025	< 1.0
AGE*AB*D	2	1.864	0.932	1.00
SD*AB*D	2	4.858	2.429	2.62
AGE*SD*AB*D	2	3.487	1.743	1.88
D*SN(AGE SD AB)	80	74.319	0.928	

* - $p < .05$

APPENDIX XI

ANALYSIS OF VARIANCE
MEAN PAUSE TIME
LIST 4

SOURCE	DF	ANOVA SS	ANOVA MS	F VALUE
AGE	1	12.632	12.632	1.69
SD	1	6.807	6.807	< 1.0
AGE*SD	1	0.510	0.510	< 1.0
SN(AGE SD AB)	40	299.058	7.476	
AB	1	3.327	3.327	< 1.0
AGE*AB	1	1.847	1.847	< 1.0
SD*AB	1	0.028	0.028	< 1.0
AGE*SD*AB	1	10.983	10.983	1.469
SN(AGE SD AB)	40	327.735	8.193	
D	2	15.522	7.761	8.363*
AGE*D	2	0.536	0.268	< 1.0
SD*D	2	1.171	0.585	< 1.0
AB*D	2	2.011	1.005	1.082
AGE*SD*D	2	5.162	2.581	2.781
AGE*AB*D	2	3.849	1.924	2.073
SD*AB*D	2	1.106	0.553	< 1.0
AGE*SD*AB*D	2	0.825	0.412	< 1.0
D*SN(AGE SD AB)	80	74.319	0.928	

* - $p < .05$

APPENDIX XII

ANALYSIS OF VARIANCE
MEAN PAUSE TIME

SAME CONDITION
LIST 2

SOURCE	DF	ANOVA SS	ANOVA MS	F VALUE
AGE	1	1.584	1.584	< 1.0
AB	1	0.078	0.078	< 1.0
SAGE*AB	1	11.568	11.568	< 1.0
SN(AGE SD AB)	1	284.798	14.239	
D	2	0.079	0.039	< 1.0
AGE*D	2	2.151	1.075	< 1.0
AB*D	2	5.137	2.568	2.17
AGE*AB*D	2	3.947	1.973	1.66
D*SN(AGE SD AB)	40	47.426	1.185	

SAME CONDITION
LIST 4

SOURCE	DF	ANOVA SS	ANOVA MS	F VALUE
AGE	1	4.032	4.032	< 1.0
AB	1	1.372	1.372	< 1.0
AGE*AB	1	10.920	10.920	< 1.0
SN(AGE SD AB)	20	263.112	13.155	
D	2	9.737	4.868	2.43
AGE*D	2	3.252	1.626	< 1.0
AB*D	2	1.883	0.941	< 1.0
AGE*AB*D	2	3.060	1.530	< 1.0
D*SN(AGE SD AB)	40	80.274	2.006	

* - p <.05

APPENDIX XIII

ANALYSIS OF VARIANCE
MEAN PAUSE TIME

ALTERNATING CONDITION
LIST 2

SOURCE	DF	ANOVA SS	ANOVA MS	F VALUE
AGE	1	11.728	11.728	5.47*
AB	1	0.002	0.002	< 1.0
AGE*AB	1	0.943	0.943	< 1.0
SN(AGE SD AB)	20	42.937	2.146	
D	2	20.685	10.342	15.39*
AGE*D	2	1.454	0.727	1.08
AB*D	2	0.944	0.4712	< 1.0
AGE*AB*D	2	1.404	0.702	1.04
D*SN(AGE SD AB)	40	26.892	0.672	

ALTERNATING CONDITION
LIST 4

SOURCE	DF	ANOVA SS	ANOVA MS	F VALUE
AGE	1	9.109	9.109	5.07*
AB	1	1.983	1.983	1.10
AGE*AB	1	1.911	1.911	1.06
SN(AGE SD AB)	20	35.945	1.797	
D	2	6.956	3.478	6.07*
AGE*D	2	2.446	1.223	2.13
AB*D	2	1.233	0.616	1.08
AGE*AB*D	2	1.614	0.807	1.41
D*SN(AGE SD AB)	40	22.951	0.573	

* - $p < .05$

APPENDIX XIV

ANALYSIS OF VARIANCE
PAUSE-TIME

SOURCE	DF	ANOVA SS	ANOVA MS	F VALUE
POS	11	142.429	12.948	9.29*
POS*AGE	11	41.641	3.785	2.72*
POS*SD	11	16.008	1.455	1.04
POS*AGE*AB	11	19.656	1.786	1.28
POS*AB	11	30.002	2.727	1.96*
POS*AGE*AB	11	22.241	2.021	1.45
POS*SD*AB	11	17.921	1.629	1.17
POS*AGE*SD*AB	11	30.249	2.749	1.97*
POS*SN(AGE SD AB)	440	613.459	1.394	
POS*L	11	12.337	1.121	1.21
POS*AGE*L	11	14.768	1.342	1.45
POS*SD*L	11	10.164	0.924	< 1.0
POS*AGE*SD*L	11	5.649	0.513	< 1.0
POS*AB*L	11	13.961	1.269	1.37
POS*AGE*AB*L	11	12.933	1.175	1.27
POS*SD*AB*L	11	7.817	0.710	< 1.0
POS*AGE*SD*AB*D	11	10.317	0.937	1.00
POS*L*SN(AGE SD AB)	440	408.685	0.928	
POS*D	22	26.208	1.191	1.15
POS*AGE*D	22	41.445	1.883	1.81*
POS*SD*D	22	22.478	1.021	< 1.0
POS*AGE*SD*D	22	22.655	1.029	< 1.0
POS*AB*D	22	17.330	0.787	< 1.0
POS*AGE*AB*D	22	34.896	1.586	1.53
POS*SD*AB*D	22	16.087	0.731	< 1.0
POS*AGE*SD*AB*D	22	29.088	1.322	1.27
POS*D*SN(AGE SD AB)	880	914.023	1.038	

* - p <.05

ANALYSIS OF VARIANCE
PAUSE-TIME

POS*L*D	22	16.998	0.772	< 1.0
POS*AGE*L*D	22	22.834	1.037	1.22
POS*SD*L*D	22	15.926	0.723	< 1.0
POS*AGE*SD*L*D	22	18.465	0.839	< 1.0
POS*AB*L*D	22	12.777	0.580	< 1.0
POS*AGE*AB*L*D	22	24.439	1.110	1.31
POS*SD*AB*L*D	22	21.350	0.970	1.14
POS*AGE*SD*AB*L*D	22	24.916	1.132	1.33
POS*L*D*SN(AGE SD AB)	880	746.281	0.848	

* - $p < .05$

APPENDIX XV

ANALYSIS OF VARIANCE
PAUSE-TIME
SAME CONDITION

SOURCE	DF	ANOVA SS	ANOVA MS	F VALUE
POS	11	79.191	7.199	5.07*
POS*AGE	11	12.909	1.173	< 1.0
POS*AB	11	35.313	3.210	2.26*
POS*AGE*AB	11	18.950	1.722	1.21
POS*SN(AGE SD AB)	220	312.504	1.420	
POS*L	11	8.512	0.773	< 1.0
POS*AGE*L	11	8.818	0.801	< 1.0
POS*AB*L	11	10.785	0.980	1.01
POS*AGE*AB*L	11	14.279	1.298	1.34
POS*L*SN(AGE SD AB)	220	213.941	0.972	
POS*D	22	34.250	1.556	1.50
POS*AGE*D	22	25.363	1.152	1.11
POS*AB*D	22	18.941	0.860	< 1.0
POS*AGE*AB*D	22	35.058	1.593	1.54
POS*D*SN(AGE SD AB)	22	455.486	1.035	
POS*L*D	22	11.986	0.544	< 1.0
POS*AGE*L*D	22	24.734	1.124	1.36
POS*AB*L*D	22	17.647	0.802	< 1.0
POS*AGE*AB*L*D	22	32.031	1.455	1.76
POS*L*D*SN(AGE SD AB)	440	363.883	0.827	

* - p <.05

APPENDIX XVI

ANALYSIS OF VARIANCE
PAUSE-TIME
ALTERNATING CONDITION

SOURCE	DF	ANOVA SS	ANOVA MS	F VALUE
POS	11	79.246	7.204	5.27*
POS*AGE	11	48.389	4.399	3.22*
POS*AB	11	12.610	1.146	< 1.0
POS*AGE*AB	11	33.540	3.049	2.23*
POS*SN(AGE SD AB)	220	300.954	1.367	
POS*L	11	13.900	1.271	1.44
POS*AGE*L	11	11.599	1.054	1.19
POS*AB*L	11	10.992	0.999	1.13
POS*AGE*AB*L	11	8.971	0.815	< 1.0
POS*L*SN(AGE SD AB)	220	194.743	0.885	
POS*D	22	14.437	0.656	< 1.0
POS*AGE*D	22	38.738	1.760	1.69*
POS*AB*D	22	14.476	0.658	< 1.0
POS*AGE*AB*D	22	28.926	1.314	1.26
POS*D*SN(AGE SD AB)	22	458.537	1.042	
POS*L*D	22	20.938	0.951	1.09
POS*AGE*L*D	22	16.565	0.752	< 1.0
POS*AB*L*D	22	16.480	0.749	< 1.0
POS*AGE*AB*L*D	22	17.324	0.787	< 1.0
POS*L*D*SN(AGE SD AB)	440	382.398	0.869	

* - $p < .05$

APPENDIX XVII

ANALYSIS OF VARIANCE
PAUSE-TIME

SAME CONDITION
THREE GROUP LISTS

SOURCE	DF	ANOVA SS	ANOVA MS	F VALUE
POS	11	60.271	5.479	4.61*
POS*AGE	11	23.073	2.097	1.84*
POS*SN(AGE SD AB)	110	130.683	1.188	
POS*L	11	12.473	1.133	< 1.0
POS*AGE*L	11	14.027	1.275	1.12
POS*L*SN(AGE SD AB)	110	125.549	1.141	
POS*D	22	16.763	0.761	< 1.0
POS*AGE*D	22	32.390	1.472	1.49
POS*D*SN(AGE SD AB)	220	217.051	0.986	
POS*L*D	22	14.616	0.664	< 1.0
POS*AGE*L*D	22	34.686	1.576	1.87*
POS*L*D*SN(AGE SD AB)	220	185.760	0.844	

* - p <.05

ANALYSIS OF VARIANCE
PAUSE-TIME

SAME CONDITION
TWO GROUP LISTS

SOURCE	DF	ANOVA SS	ANOVA MS	F VALUE
POS	11	54.232	4.930	6.18*
POS*AGE	11	8.786	0.798	< 1.0
POS*SN(AGE SD AB)	110	181.821	1.652	
POS*L	11	6.825	0.620	< 1.0
POS*AGE*L	11	9.071	0.824	1.03
POS*L*SN(AGE SD AB)	110	88.391	0.803	
POS*D	22	36.428	1.655	1.53
POS*AGE*D	22	28.031	1.274	1.18
POS*D*SN(AGE SD AB)	220	238.435	1.083	1.18
POS*L*D	22	15.017	0.682	< 1.0
POS*AGE*L*D	22	22.079	1.003	1.24
POS*L*D*SN(AGE SD AB)	220	178.122	0.809	

* - $p < .05$

APPENDIX XVIII

ANALYSIS OF VARIANCE
PAUSE-TIME

ALTERNATING CONDITION
THREE GROUP LISTS

SOURCE	DF	ANOVA SS	ANOVA MS	F VALUE
POS	11	46.572	4.233	3.49*
POS*AGE	11	8.956	0.814	< 1.0
POS*SN(AGE SD AB)	110	133.325	1.212	
POS*L	11	20.835	1.894	2.07*
POS*AGE*L	11	12.639	1.149	1.25*
POS*L*SN(AGE SD AB)	110	100.816	0.916	
POS*D	22	12.340	0.560	< 1.0
POS*AGE*D	22	39.425	1.792	1.58*
POS*D*SN(AGE SD AB)	220	250.112	1.136	
POS*L*D	22	14.108	0.641	< 1.0
POS*AGE*L*D	22	20.842	0.947	1.04*
POS*L*D*SN(AGE SD AB)	220	1999.873	0.908	

* - $p < .05$

ANALYSIS OF VARIANCE
PAUSE-TIME

ALTERNATING CONDITION
TWO GROUP LISTS

SOURCE	DF	ANOVA SS	ANOVA MS	F VALUE
POS	11	45.285	4.116	2.70*
POS*AGE	11	72.973	6.633	4.36*
POS*SN(AGE SD AB)	110	167.628	1.523	
POS*L	11	4.147	0.377	< 1.0
POS*AGE*L	11	7.931	0.721	< 1.0
POS*L*SN(AGE SD AB)	110	93.927	0.853	
POS*D	22	16.573	0.753	< 1.0
POS*AGE*D	22	28.239	1.283	1.35
POS*D*SN(AGE SD AB)	220	208.425	0.947	
POS*L*D	22	23.309	1.059	1.28
POS*AGE*L*D	22	13.047	0.593	< 1.0
POS*L*D*SN(AGE SD AB)	220	182.524	0.829	

* - $p < .05$

APPENDIX XIX

TREND ANALYSES
POSITIONS 1-12

THREE GROUP LISTS

SOURCE	DF	ANOVA SS	ANOVA MS	F VALUE
POS*LIN/	1/	41.390/	41.390/	14.16*
POS*SN(AGE SD AB)	20	58.496	2.924	
POS*QUAD/	1/	16.383/	16.383/	11.12*
POS*SN(AGE SD AB)	20	29.462	1.473	
POS*CUB/	1/	8.196/	8.196/	6.03*
POS*SN(AGE SD AB)	20	27.984	1.359	
POS*QUAR/	1/	10.701	10.701	7.81*
POS*SN(AGE SD AB)	20	27.420/	1.371/	
POS*QUIN/	1/	0.030	0.030	< 1.0
POS*SN(AGE SD AB)	20	13.145	0.779	

* - p <.05

TWO GROUP LISTS

SOURCE	DF	ANOVA SS	ANOVA MS	F VALUE
POS*LIN/ POS*SN(AGE SD AB)	1/ 20	4.784/ 93.324/	4.784/ 4.666	1.03
POS*QUAD/ POS*SN(AGE SD AB)	1/ 20	66.317/ 41.233	66.317/ 2.061	32.18*
POS*CUB/ POS*SN(AGE SD AB)	1/ 20	8.369/ 37.468	8.369 1.873	4.47
POS*QUAR/ POS*SN(AGE SD AB)	1/ 20	2.339/ 36.090	2.339/ 1.804	1.30
POS*QUIN/ POS*SN(AGE SD AB)	1/ 20	0.271/ 23.875	0.271/ 1.193	< 1.0

* - $p < .05$

THREE GROUP LISTS
SAME CONDITION

SOURCE	DF	ANOVA SS	ANOVA MS	F VALUE
POS*LIN/ POS*SN(AGE SD AB)	1/ 10	28.660/ 13.218	28.660/ 1.321	21.70*
POS*QUAD/ POS*SN(AGE SD AB)	1/ 10	2.875/ 19.335	2.875/ 1.933	1.49
POS*CUB/ POS*SN(AGE SD AB)	1/ 10	3.684/ 13.635	3.684/ 1.363	2.70
POS*QUAR/ POS*SN(AGE SD AB)	1/ 10	14.716/ 5.862	14.716/ 0.586	25.11*
POS*QUIN/ POS*SN(AGE SD AB)	1/ 10	0.262/ 7.817	0.262/ 0.781	< 1.0

TWO GROUP LISTS
SAME CONDITION

SOURCE	DF	ANOVA SS	ANOVA MS	F VALUE
POS*LIN/ POS*SN(AGE SD AB)	1/ 10	14.023/ 45.278	14.023/ 4.527	3.10
POS*QUAD/ POS*SN(AGE SD AB)	1/ 10	16.228/ 10.127	16.228/ 11.012	16.03*
POS*CUB/ POS*SN(AGE SD AB)	1/ 10	4.533/ 14.348	4.533/ 1.434	3.16
POS*QUAR/ POS*SN(AGE SD AB)	1/ 10	0.624/ 21.557	0.624/ 2.155	< 1.0
POS*QUIN/ POS*SN(AGE SD AB)	1/ 10	0.577/ 5.327	0.577/ 0.532	1.08

* - $p < .05$

ALTERNATING CONDITION
THREE GROUP LISTS

SOURCE	DF	ANOVA SS	ANOVA MS	F VALUE
POS*LIN/	1/	0.431	0.431/	< 1.0
POS*SN(AGE SD AB)	10	55.109	5.510	
POS*QUAD/	1/	42.093/	42.093/	15.54*
POS*SN(AGE SD AB)	10	27.097	2.790	
POS*CUB/	1/	2.591/	2.591/	1.85
POS*SN(AGE SD AB)	10	17.139	1.713	
POS*QUAR/	1/	4.554/	4.554/	2.66
POS*SN(AGE SD AB)	10	17.139	1.713	
POS*QUIN/	1/	1.440/	1.440/	1.31
POS*SN(AGE SD AB)	10	11.034	1.103	

ALTERNATING CONDITION
TWO GROUP LISTS

SOURCE	DF	ANOVA SS	ANOVA MS	F VALUE
POS*LIN/	1/	5.938/	5.938/	1.55
POS*SN(AGE SD AB)	10	38.214	3.821	
POS*QUAD/	1/	6.157/	6.157/	17.90*
POS*SN(AGE SD AB)	10	14.135	1.413	
POS*CUB/	1/	6.157/	6.157/	2.63
POS*SN(AGE SD AB)	10	23.439	2.343	
POS*QUAR/	1/	0.000/	0.000/	< 1.0
POS*SN(AGE SD AB)	10	18.951	1.895	
+POS*QUIN/	1/	0.214	0.214/	< 1.0
POS*SN(AGE SD AB)	10	12.840	1.284	

* - p <.05

SAME CONDITION
THREE GROUP LISTS
OLD SUBJECTS

SOURCE	DF	ANOVA SS	ANOVA MS	F VALUE
POS*LIN/ POS*SN(AGE SD AB)	1/ 5	46.564/ 2.871	46.564/ 0.574	4.40
POS*QUAD/ POS*SN(AGE SD AB)	1/ 5	0.261/ 6.030	0.261 1.206	< 1.0
POS*CUB/ POS*SN(AGE SD AB)	1/ 5	2.118/ 5.344	2.118/ 1.068	1.98
POS*QUAR/ POS*SN(AGE SD AB)	1/ 5	14.129/ 2.242	14.129/ 0.448	31.53*
POS*QUIN/ POS*SN(AGE SD AB)	1/ 5	0.126/ 2.161	0.126/ 0.432	< 1.0

SAME CONDITION
THREE GROUP LISTS
YOUNG SUBJECTS

SOURCE	DF	ANOVA SS	ANOVA MS	F VALUE
POS*LIN/ POS*SN(AGE SD AB)	1/ 5	0.558/ 10.346	0.558/ 2.069	< 1.0
POS*QUAD/ POS*SN(AGE SD AB)	1/ 5	3.559 13.305	3.559 2.661	1.34
POS*CUB/ POS*SN(AGE SD AB)	1/ 5	1.585 8.291	1.585 1.658	< 1.0
POS*QUAR/ POS*SN(AGE SD AB)	1/ 5	2.776 3.619	2.776 0.723	3.84
POS*QUIN/ POS*SN(AGE SD AB)	1/ 5	1.165 5.656	1.165 1.131	1.03

* - $p < .05$

SAME CONDITION
TWO GROUP LISTS
OLD SUBJECTS

SOURCE	DF	ANOVA SS	ANOVA MS	F VALUE
POS*LIN/ POS*SN(AGE SD AB)	1/ 5	0.011/ 21.120	0.011/ 4.224	< 1.0
POS*QUAD/ POS*SN(AGE SD AB)	1/ 5	14.908/ 17.880	14.908/ 3.576	4.17
POS*CUB/ POS*SN(AGE SD AB)	1/ 5	0.465/ 13.520	0.465/ 2.270	< 1.0
POS*QUAR/ POS*SN(AGE SD AB)	1/ 5	1.074/ 8.603	1.074/ 1.720	< 1.0
POS*QUIN/ POS*SN(AGE SD AB)	1/ 5	0.128/ 7.623	0.128/ 1.524	< 1.0

SAME CONDITION
TWO GROUP LISTS
YOUNG SUBJECTS

SOURCE	DF	ANOVA SS	ANOVA MS	F VALUE
POS*LIN/ POS*SN(AGE SD AB)	1/ 5	1.067 33.989	1.067 6.797	< 1.0
POS*QUAD/ POS*SN(AGE SD AB)	1/ 5	28.241/ 9.216	28.241/ 1.843	15.32*
POS*CUB/ POS*SN(AGE SD AB)	1/ 5	2.541/ 2.677	2.541/ 0.535	4.75
POS*QUAR/ POS*SN(AGE SD AB)	1/ 5	3.925/ 8.535	3.925/ 1.707	2.30
POS*QUIN/ POS*SN(AGE SD AB)	1/ 5	1.793/ 3.411	1.793/ 0.682	2.63

* - p <.05

ALTERNATING CONDITION
THREE GROUP LISTS
OLD SUBJECTS

SOURCE	DF	ANOVA SS	ANOVA MS	F VALUE
POS*LIN/ POS*SN(AGE SD AB)	1/ 5	10.671/ 12.648	10.671/ 2.529	4.22
POS*QUAD/ POS*SN(AGE SD AB)	1/ 5	4.161/ 6.496	4.161/ 1.299	3.20
POS*CUB/ POS*SN(AGE SD AB)	1/ 5	0.960/ 10.058	0.960/ 2.011	< 1.0
POS*QUAR/ POS*SN(AGE SD AB)	1/ 5	0.604/ 11.831	0.604/ 2.306	< 1.0
POS*QUIN/ POS*SN(AGE SD AB)	1/ 5	0.270/ 2.231	0.270/ 0.446	< 1.0

ALTERNATING CONDITION
THREE GROUP LISTS
YOUNG SUBJECTS

SOURCE	DF	ANOVA SS	ANOVA MS	F VALUE
POS*LIN/ POS*SN(AGE SD AB)	1/ 5	4.118/ 32.630	4.118/ 6.526	< 1.0
POS*QUAD/ POS*SN(AGE SD AB)	1/ 5	13.375/ 3.631	13.375/ 0.726	18.42*
POS*CUB/ POS*SN(AGE SD AB)	1/ 5	4.126/ 4.289	4.126/ 0.857	4.81
POS*QUAR/ POS*SN(AGE SD AB)	1/ 5	0.115 9.725	0.115 1.945	< 1.0
POS*QUIN/ POS*SN(AGE SD AB)	1/ 5	0.307/ 3.095	0.307/ 0.619	< 1.0

* - p <.05

ALTERNATING CONDITION
TWO GROUP LISTS
OLD SUBJECTS

SOURCE	DF	ANOVA SS	ANOVA MS	F VALUE
POS*LIN/	1/	27.380	27.380	13.47*
POS*SN(AGE SD AB)	5	10.172	2.034	
POS*QUAD/	1/	1.235	1.235	< 1.0
POS*SN(AGE SD AB)	5	7.719	1.543	
POS*CUB/	1/	0.594	0.594	< 1.0
POS*SN(AGE SD AB)	5	10.309	2.061	
POS*QUAR/	1/	8.842	8.842	4.05
POS*SN(AGE SD AB)	5	10.909	2.181	
POS*QUIN/	1/	3.835	3.835	3.51
POS*SN(AGE SD AB)	5	5.474	1.094	

ALTERNATING CONDITION
TWO GROUP LISTS
YOUNG SUBJECTS

SOURCE	DF	ANOVA SS	ANOVA MS	F VALUE
POS*LIN/	1/	3.190/	3.190/	< 1.0
POS*SN(AGE SD AB)	5	28.042	5.608	
POS*QUAD/	1/	36.001/	36.001/	28.06*
POS*SN(AGE SD AB)	5	6.415	1.283	
POS*CUB/	1/	7.498/	7.498/	2.86
POS*SN(AGE SD AB)	5	13.129	2.625	
POS*QUAR/	1/	9.089/	9.089/	5.65
POS*SN(AGE SD AB)	5	8.041	1.608	
POS*QUIN/	1/	6.828/	6.828/	4.64
POS*SN(AGE SD AB)	5	7.366	1.473	

* - p <.05

APPENDIX XX

TREND ANALYSES
POSITION BLOCKS 1-6

THREE GROUP LISTS

SOURCE	DF	ANOVA SS	ANOVA MS	F VALUE
POS*LIN/ POS*SN(AGE SD AB)	1/ 20	21.619/ 28.287	21.619/ 1.414	15.40*
POS*QUAD/ POS*SN(AGE SD AB)	1/ 20	6.471/ 14.989	6.471/ 0.749	8.64*
POS*CUB/ POS*SN(AGE SD AB)	1/ 20	2.315/ 11.086	2.315/ 0.554	4.18
POS*QUAR/ POS*SN(AGE SD AB)	1/ 20	1.404/ 10.951	1.404/ 0.547	2.57
POS*QUIN/ POS*SN(AGE SD AB)	1/ 20	0.634/ 0.082	0.634/ 0.404	1.569

* - $p < .05$

TWO GROUP LISTS

SOURCE	DF	ANOVA SS	ANOVA MS	F VALUE
POS*LIN/ POS*SN(AGE SD AB)	1/ 20	2.150/ 45.546	2.150/ 2.277	< 1.0
POS*QUAD/ POS*SN(AGE SD AB)	1/ 20	26.507/ 17.215	26.507/ 0.860	30.82*
POS*CUB/ POS*SN(AGE SD AB)	1/ 20	2.920/ 19.869	2.920/ 0.993	2.94
POS*QUAR/ POS*SN(AGE SD AB)	1/ 20	0.743/ 16.005	0.743/ 0.800	< 1.0
POS*QUIN/ POS*SN(AGE SD AB)	1/ 20	0.001 9.754	0.001 0.487	< 1.0

* - $p < .05$

SAME CONDITION
THREE GROUP LISTS

SOURCE	DF	ANOVA SS	ANOVA MS	F VALUE
POS*LIN/ POS*SN(AGE SD AB)	1/ 10	15.217/ 6.165	15.217/ 0.616	24.70*
POS*QUAD/ POS*SN(AGE SD AB)	1/ 10	0.608/ 10.656	0.608/ 1.065	< 1.0
POS*CUB/ POS*SN(AGE SD AB)	1/ 10	2.409/ 4.128	2.409/ 0.412	5.85*
POS*QUAR/ POS*SN(AGE SD AB)	1/ 10	3.796/ 2.199	3.796 0.219	17.33*
POS*QUIN/ POS*SN(AGE SD AB)	1/ 10	0.233/ 4.996	0.233/ 0.499	< 1.0

SAME CONDITION
TWO GROUP LISTS

SOURCE	DF	ANOVA SS	ANOVA MS	F VALUE
POS*LIN/ POS*SN(AGE SD AB)	1/ 10	7.154/ 22.122	7.154/ 2.212	3.234
POS*QUAD/ POS*SN(AGE SD AB)	1/ 10	8.075/ 4.332	8.075/ 0.433	18.65*
POS*CUB/ POS*SN(AGE SD AB)	1/ 10	0.359/ 6.957	0.359/ 0.695	< 1.0
POS*QUAR/ POS*SN(AGE SD AB)	1/ 10	0.074/ 8.751	0.074/ 0.875	< 1.0
POS*QUIN/ POS*SN(AGE SD AB)	1/ 10	0.413/ 3.085	0.413/ 0.308	1.34

* - $p < .05$

ALTERNATING CONDITION
THREE GROUP LISTS

SOURCE	DF	ANOVA SS	ANOVA MS	F VALUE
POS*LIN/ POS*SN(AGE SD AB)	1/ 10	0.215/ 27.356	0.215/ 2.735	< 1.0
POS*QUAD/ POS*SN(AGE SD AB)	1/ 10	17.757/ 12.332	17.757/ 1.233	14.40*
POS*CUB/ POS*SN(AGE SD AB)	1/ 10	0.857/ 7.287	0.857/ 0.728	1.18
POS*QUAR/ POS*SN(AGE SD AB)	1/ 10	1.314/ 10.190	1.314/ 1.019	1.29
POS*QUIN/ POS*SN(AGE SD AB)	1/ 10	0.579/ 6.617	0.579/ 0.661	< 1.0

ALTERNATING CONDITION
TWO GROUP LISTS

SOURCE	DF	ANOVA SS	ANOVA MS	F VALUE
POS*LIN/ POS*SN(AGE SD AB)	1/ 10	2.590/ 18.190	2.590/ 1.819	1.42
POS*QUAD/ POS*SN(AGE SD AB)	1/ 10	9.407/ 4.882	9.407/ 0.488	19.28*
POS*CUB/ POS*SN(AGE SD AB)	1/ 10	2.222/ 12.582	2.222/ 1.258	1.77
POS*QUAR/ POS*SN(AGE SD AB)	1/ 10	0.005/ 5.814	0.005/ 0.581	< 1.0
POS*QUIN/ POS*SN(AGE SD AB)	1/ 10	0.489/ 3.137	0.489/ 0.313	1.56

* - $p < .05$

SAME CONDITION
THREE GROUP LISTS
OLD SUBJECTS

SOURCE	DF	ANOVA SS	ANOVA MS	F VALUE
POS*LIN/	1/	24.070/	24.070/	113.00*
POS*SN(AGE SD AB)	5	1.065	0.213	
POS*QUAD/	1/	0.000/	0.000/	< 1.0
POS*SN(AGE SD AB)	5	3.779	0.755	
POS*CUB/	1/	0.826/	0.826/	2.039
POS*SN(AGE SD AB)	5	2.028	0.405	
POS*QUAR/	1/	4.100/	4.100/	20.50*
POS*SN(AGE SD AB)	5	1.001	0.200	
POS*QUIN/	1/	0.310/	0.310/	< 1.0
POS*SN(AGE SD AB)	5	2.631	0.526	

SAME CONDITION
THREE GROUP LISTS
YOUNG SUBJECTS

SOURCE	DF	ANOVA SS	ANOVA MS	F VALUE
POS*LIN/	1/	0.372/	0.372/	< 1.0
POS*SN(AGE SD AB)	5	5.099	1.019	
POS*QUAD/	1/	1.179/	1.179/	< 1.0
POS*SN(AGE SD AB)	5	6.877	1.375	
POS*CUB/	1/	1.654/	1.654/	3.95
POS*SN(AGE SD AB)	5	2.099	0.419	
POS*QUAR/	1/	0.533/	0.533/	2.23
POS*SN(AGE SD AB)	5	1.196	0.239	
POS*QUIN/	1/	0.015/	0.015/	< 1.0
POS*SN(AGE SD AB)	5	2.365	0.473	

* - $p < .05$

SAME CONDITION
TWO GROUP LISTS
OLD SUBJECTS

SOURCE	DF	ANOVA SS	ANOVA MS	F VALUE
POS*LIN/ POS*SN(AGE SD AB)	1/ 5	0.036/ 10.907	0.036/ 1.066	< 1.0
POS*QUAD/ POS*SN(AGE SD AB)	1/ 5	7.161/ 7.198	7.161/ 1.314	4.98
POS*CUB/ POS*SN(AGE SD AB)	1/ 5	0.092/ 6.571	0.092/ 1.314	< 1.0
POS*QUAR/ POS*SN(AGE SD AB)	1/ 5	0.125/ 5.462	0.125/ 1.092	< 1.0
POS*QUIN/ POS*SN(AGE SD AB)	1/ 5	0.043 2.639	0.043/ 0.527	< 1.0

SAME CONDITION
TWO GROUP LISTS
YOUNG SUBJECTS

SOURCE	DF	ANOVA SS	ANOVA MS	F VALUE
POS*LIN/ POS*SN(AGE SD AB)	1/ 5	0.716/ 16.449	0.716/ 3.289	< 1.0
POS*QUAD/ POS*SN(AGE SD AB)	1/ 5	10.780/ 5.134	10.780/ 1.026	10.50*
POS*CUB/ POS*SN(AGE SD AB)	1/ 5	1.009/ 0.716	1.009/ 0.143	< 1.0 < 1.0
POS*QUAR/ POS*SN(AGE SD AB)	1/ 5	1.605/ 4.727	1.605/ 0.945	1.70
POS*QUIN/ POS*SN(AGE SD AB)	1/ 5	0.752/ 3.977	0.752/ 0.795	< 1.0

* - p <.05

ALTERNATING CONDITION
THREE GROUP LISTS
OLD SUBJECTS

SOURCE	DF	ANOVA SS	ANOVA MS	F VALUE
POS*LIN/ POS*SN(AGE SD AB)	1/ 5	5.518/ 6.246	5.518/ 1.249	4.47
POS*QUAD/ POS*SN(AGE SD AB)	1/ 5	2.232/ 2.019	2.232/ 0.403	5.54
POS*CUB/ POS*SN(AGE SD AB)	1/ 5	0.026/ 4.628	0.026/ 0.925	< 1.0
POS*QUAR/ POS*SN(AGE SD AB)	1/ 5	0.038/ 3.981	0.038/ 0.796	< 1.0
POS*QUIN/ POS*SN(AGE SD AB)	1/ 5	0.001/ 1.105	0.001/ 0.221	< 1.0

ALTERNATING CONDITION
THREE GROUP LISTS
YOUNG SUBJECTS

SOURCE	DF	ANOVA SS	ANOVA MS	F VALUE
POS*LIN/ POS*SN(AGE SD AB)	1/ 5	2.055/ 15.876	2.055/ 3.175	< 1.0
POS*QUAD/ POS*SN(AGE SD AB)	1/ 5	6.373/ 2.312	6.373/ 0.462	13.79*
POS*CUB/ POS*SN(AGE SD AB)	1/ 5	1.023/ 0.339	1.023/ 0.339	2.20
POS*QUAR/ POS*SN(AGE SD AB)	1/ 5	0.339 4.770	0.339 0.954	< 1.0
POS*QUIN/ POS*SN(AGE SD AB)	1/ 5	0.882/ 1.980	0.882/ 0.396	2.23

* - p <.05

ALTERNATING CONDITION
TWO GROUP LISTS
OLD SUBJECTS

SOURCE	DF	ANOVA SS	ANOVA MS	F VALUE
POS*LIN/ POS*SN(AGE SD AB)	1/ 5	12.166/ 5.870	12.166/ 1.174	10.36*
POS*QUAD/ POS*SN(AGE SD AB)	1/ 5	1.171/ 2.461	1.171/ 0.492	2.38
POS*CUB/ POS*SN(AGE SD AB)	1/ 5	1.330/ 4.172	1.330/ 0.834	1.59
POS*QUAR/ POS*SN(AGE SD AB)	1/ 5	0.455/ 1.793	0.455/ 0.358	< 1.0
POS*QUIN/ POS*SN(AGE SD AB)	1/ 5	0.170/ 1.267	0.170/ 0.253	< 1.0

ALTERNATING CONDITION
TWO GROUP LISTS
YOUNG SUBJECTS

SOURCE	DF	ANOVA SS	ANOVA MS	F VALUE
POS*LIN/ POS*SN(AGE SD AB)	1/ 5	1.468/ 12.319	1.468/ 2.463	< 1.0
POS*QUAD/ POS*SN(AGE SD AB)	1/ 5	10.597/ 2.420	10.597/ 0.484	21.89*
POS*CUB/ POS*SN(AGE SD AB)	1/ 5	0.911/ 8.409	0.911/ 1.691	< 1.0
POS*QUAR/ POS*SN(AGE SD AB)	1/ 5	0.605/ 4.021	0.605/ 0.804	< 1.0
POS*QUIN/ POS*SN(AGE SD AB)	1/ 5	0.332/ 1.869	0.332/ 0.373	< 1.0

* - $p < .05$

APPENDIX XXI

STANDARDIZED PAUSE-TIME BY POSITION

OLD SUBJECTS
SAME CONDITION
THREE GROUP LISTS
LIST TWO

LOAD = 0

POSITION	1	2	3	4	5	6
MEAN	3.803	4.000	4.948	4.473	4.234	4.101
(SD)	(0.661)	(1.011)	(1.546)	(1.511)	(1.305)	(0.699)

POSITION	7	8	9	10	11	12
MEAN	3.414	4.017	3.594	4.215	3.606	3.476
(SD)	(0.342)	(0.904)	(0.598)	(1.211)	(0.663)	(0.591)

LOAD = 2

POSITION	1	2	3	4	5	6
MEAN	5.317	4.306	4.826	3.969	3.862	3.542
(SD)	(0.890)	(0.973)	(1.140)	(1.127)	(0.257)	(0.708)

POSITION	7	8	9	10	11	12
MEAN	3.772	4.130	3.621	3.576	3.890	3.187
(SD)	(0.971)	(1.274)	(0.961)	(0.989)	(0.512)	(0.479)

LOAD = 4

POSITION	1	2	3	4	5	6
MEAN	4.044	4.520	4.615	5.062	4.205	3.936
(SD)	(1.198)	(1.060)	(1.027)	(1.158)	(0.812)	(0.564)

POSITION	7	8	9	10	11	12
MEAN	3.507	3.922	4.319	3.583	3.560	2.722
(SD)	(0.526)	(1.046)	(1.116)	(0.449)	(0.288)	(0.747)

OLD SUBJECTS
SAME CONDITION
TWO GROUP LISTS
LIST FOUR

LOAD = 0

POSITION	1	2	3	4	5	6
MEAN	3.810	4.969	4.034	5.023	3.850	3.349
(SD)	(1.238)	(1.577)	(1.279)	(0.837)	(0.651)	(0.541)

POSITION	7	8	9	10	11	12
MEAN	4.222	3.926	3.820	3.811	3.562	3.618
(SD)	(1.042)	(0.550)	(0.753)	(0.474)	(0.425)	(1.205)

LOAD = 2

POSITION	1	2	3	4	5	6
MEAN	4.161	5.242	4.638	4.899	4.171	4.127
(SD)	(0.884)	(1.184)	(0.935)	(0.676)	(1.149)	(0.670)

POSITION	7	8	9	10	11	12
MEAN	3.528	3.754	3.605	3.263	3.599	3.071
(SD)	(0.624)	(0.497)	(0.888)	(0.763)	(0.814)	(0.752)

LOAD = 4

POSITION	1	2	3	4	5	6
MEAN	3.764	4.437	4.413	4.215	4.293	3.801
(SD)	(1.292)	(1.190)	(0.880)	(0.459)	(0.501)	(0.803)

POSITION	7	8	9	10	11	12
MEAN	3.295	3.959	3.776	4.293	3.738	4.001
(SD)	(0.622)	(1.384)	(1.222)	(0.896)	(1.099)	(1.441)

OLD SUBJECTS
SAME CONDITION
TWO GROUP LIST
LIST TWO

LOAD = 0

POSITION	1	2	3	4	5	6
MEAN	3.470	3.343	4.368	3.739	4.311	4.360
(SD)	(1.228)	(0.796)	(0.705)	(1.086)	(1.143)	(0.635)

POSITION	7	8	9	10	11	12
MEAN	4.498	3.549	4.569	4.070	3.986	3.727
(SD)	(1.196)	(0.928)	(1.500)	(1.022)	(0.632)	(0.709)

LOAD = 2

POSITION	1	2	3	4	5	6
MEAN	3.034	4.482	4.075	3.909	4.349	3.605
(SD)	(1.018)	(1.259)	(0.817)	(0.950)	(1.338)	(0.785)

POSITION	7	8	9	10	11	12
MEAN	4.829	4.059	4.127	4.105	3.821	3.591
(SD)	(0.984)	(1.105)	(0.567)	(1.206)	(0.627)	(0.784)

LOAD = 4

POSITION	1	2	3	4	5	6
MEAN	4.193	4.107	3.639	3.917	3.894	4.444
(SD)	(1.899)	(1.021)	(0.577)	(1.179)	(0.419)	(0.990)

POSITION	7	8	9	10	11	12
MEAN	4.544	4.115	3.344	4.541	3.749	3.507
(SD)	(1.187)	(0.944)	(0.721)	(0.968)	(0.804)	(0.624)

OLD SUBJECTS
SAME CONDITION
TWO GROUP LISTS
LIST FOUR

LOAD = 0

POSITION	1	2	3	4	5	6
MEAN	4.458	3.505	4.292	3.999	4.600	4.582
(SD)	(1.757)	(0.447)	(0.870)	(1.072)	(1.706)	(1.003)

POSITION	7	8	9	10	11	12
MEAN	3.868	3.523	3.834	3.794	3.526	3.848
(SD)	(0.469)	(0.553)	(0.579)	(0.966)	(1.280)	(0.523)

LOAD = 2

POSITION	1	2	3	4	5	6
MEAN	2.785	3.399	4.099	3.613	4.452	3.826
(SD)	(0.698)	(0.751)	(1.070)	(1.225)	(0.695)	(0.920)

POSITION	7	8	9	10	11	12
MEAN	4.538	4.373	4.311	4.368	4.671	3.559
(SD)	(0.907)	(0.601)	(0.887)	(1.172)	(1.113)	(0.738)

LOAD = 4

POSITION	1	2	3	4	5	6
MEAN	3.430	4.269	4.737	4.616	4.312	3.699
(SD)	(1.369)	(1.467)	(0.793)	(0.813)	(1.444)	(0.696)

POSITION	7	8	9	10	11	12
MEAN	3.513	4.226	3.939	3.900	3.645	3.711
(SD)	(0.754)	(0.842)	(0.423)	(0.866)	(1.182)	(0.695)

OLD SUBJECTS
ALTERNATING CONDITION
THREE GROUP LISTS
LIST TWO

LOAD = 0

POSITION	1	2	3	4	5	6
MEAN	4.442	4.609	4.409	3.701	4.461	3.500
(SD)	(1.431)	(1.282)	(1.338)	(1.295)	(1.146)	(0.235)

POSITION	7	8	9	10	11	12
MEAN	3.929	3.824	4.054	4.284	3.392	3.402
(SD)	(0.888)	(0.933)	(0.959)	(1.253)	(0.788)	(0.406)

LOAD = 2

POSITION	1	2	3	4	5	6
MEAN	4.861	4.594	4.745	4.282	3.807	3.492
(SD)	(1.440)	(1.120)	(1.558)	(1.189)	(0.602)	(0.610)

POSITION	7	8	9	10	11	12
MEAN	3.731	4.381	3.851	3.691	3.200	3.363
(SD)	(0.657)	(0.566)	(0.983)	(0.273)	(0.473)	(0.629)

LOAD = 4

POSITION	1	2	3	4	5	6
MEAN	3.670	4.067	4.003	3.753	4.643	4.802
(SD)	(0.993)	(0.931)	(0.994)	(0.560)	(1.068)	(1.017)

POSITION	7	8	9	10	11	12
MEAN	4.063	4.626	3.742	3.593	4.395	2.638
(SD)	(0.814)	(0.951)	(1.061)	(0.472)	(0.799)	(0.934)

OLD SUBJECTS
ALTERNATING LISTS
THREE GROUP LISTS
LIST FOUR

LOAD = 0

POSITION	1	2	3	4	5	6
MEAN	3.377	4.349	3.876	4.870	4.994	3.169
(SD)	(0.661)	(1.062)	(0.794)	(0.940)	(0.721)	(0.514)

POSITION	7	8	9	10	11	12
MEAN	4.431	3.691	3.714	4.312	3.368	3.844
(SD)	(1.290)	(0.872)	(0.727)	(1.447)	(0.570)	(0.741)

LOAD = 2

POSITION	1	2	3	4	5	6
MEAN	3.860	3.979	3.578	4.524	4.296	3.859
(SD)	(1.803)	(1.335)	(0.559)	(1.364)	(0.631)	(0.632)

POSITION	7	8	9	10	11	12
MEAN	4.132	3.551	3.877	4.707	3.681	3.952
(SD)	(0.963)	(0.402)	(0.476)	(1.355)	(0.755)	(0.972)

LOAD = 4

POSITION	1	2	3	4	5	6
MEAN	3.331	4.087	4.254	4.047	4.390	4.241
(SD)	(1.420)	(0.615)	(0.758)	(0.899)	(1.403)	(0.709)

POSITION	7	8	9	10	11	12
MEAN	4.213	4.080	3.654	3.573	3.324	4.798
(SD)	(0.646)	(1.268)	(1.021)	(0.804)	(0.800)	(1.087)

OLD SUBJECTS
ALTERNATING LISTS
TWO GROUP LISTS
LIST TWO

LOAD = 0

POSITION	1	2	3	4	5	6
MEAN	5.349	4.038	4.025	4.157	4.077	4.566
(SD)	(1.419)	(1.169)	(0.886)	(1.099)	(0.370)	(0.955)

POSITION	7	8	9	10	11	12
MEAN	4.304	3.958	3.783	3.185	3.382	3.172
(SD)	(0.681)	(1.453)	(0.476)	(0.306)	(0.369)	(0.301)

LOAD = 2

POSITION	1	2	3	4	5	6
MEAN	4.964	3.890	4.409	4.819	3.926	3.483
(SD)	(0.985)	(0.892)	(1.145)	(0.964)	(0.617)	(0.749)

POSITION	7	8	9	10	11	12
MEAN	4.772	3.127	3.586	3.473	4.050	3.496
(SD)	(0.827)	(0.608)	(0.396)	(0.953)	(1.427)	(0.599)

LOAD = 4

POSITION	1	2	3	4	5	6
MEAN	3.913	4.103	4.067	4.359	4.777	4.466
(SD)	(1.162)	(0.928)	(0.633)	(1.240)	(0.743)	(1.046)

POSITION	7	8	9	10	11	12
MEAN	3.476	3.645	3.767	3.608	3.793	4.023
(SD)	(1.398)	(0.798)	(0.730)	(1.091)	(1.168)	(0.987)

OLD SUBJECTS
ALTERNATING LISTS
TWO GROUP LISTS
LIST FOUR

LOAD = 0

POSITION	1	2	3	4	5	6
MEAN	4.432	3.549	4.283	4.193	4.269	3.646
(SD)	(1.735)	(0.877)	(1.422)	(0.978)	(1.143)	(0.649)
POSITION	7	8	9	10	11	12
MEAN	4.523	4.173	4.009	3.694	3.541	3.683
(SD)	(1.362)	(0.754)	(0.911)	(0.510)	(0.611)	(0.576)

LOAD = 2

POSITION	1	2	3	4	5	6
MEAN	4.493	4.208	4.378	4.516	4.203	4.553
(SD)	(0.598)	(1.087)	(0.950)	(0.838)	(0.569)	(0.757)
POSITION	7	8	9	10	11	12
MEAN	5.018	3.637	3.114	3.352	3.430	3.094
(SD)	(1.028)	(0.596)	(0.620)	(0.901)	(1.009)	(1.127)

LOAD = 4

POSITION	1	2	3	4	5	6
MEAN	4.217	3.169	4.113	4.115	3.915	4.570
(SD)	(1.884)	(0.544)	(0.465)	(0.795)	(0.609)	(1.190)
POSITION	7	8	9	10	11	12
MEAN	4.074	3.744	4.112	3.818	3.650	4.497
(SD)	(1.448)	(0.859)	(0.879)	(0.477)	(1.137)	(1.021)

YOUNG SUBJECTS
SAME CONDITIONS
THREE GROUP LISTS
LIST TWO

LOAD = 0

POSITION	1	2	3	4	5	6
MEAN	4.174	3.720	4.321	4.596	4.300	4.054
(SD)	(1.882)	(0.636)	(1.293)	(0.646)	(1.311)	(0.359)

POSITION	7	8	9	10	11	12
MEAN	4.359	3.531	3.761	3.614	3.729	3.838
(SD)	(1.255)	(1.069)	(0.261)	(0.200)	(0.798)	(1.216)

LOAD = 2

POSITION	1	2	3	4	5	6
MEAN	2.922	3.724	3.697	5.290	3.799	4.435
(SD)	(0.675)	(1.141)	(1.197)	(1.448)	(0.580)	(0.680)

POSITION	7	8	9	10	11	12
MEAN	3.577	3.962	4.194	4.321	4.608	3.464
(SD)	(0.545)	(0.588)	(0.601)	(0.512)	(1.165)	(0.804)

LOAD = 4

POSITION	1	2	3	4	5	6
MEAN	4.729	4.630	4.451	3.885	3.979	4.405
(SD)	(1.610)	(0.636)	(0.976)	(1.588)	(0.772)	(1.243)

POSITION	7	8	9	10	11	12
MEAN	3.573	3.703	3.712	3.787	3.305	3.814
(SD)	(0.512)	(0.525)	(0.381)	(0.876)	(0.373)	(1.222)

YOUNG SUBJECTS
SAME CONDITION
THREE GROUP LISTS
LIST FOUR

LOAD = 0

POSITION	1	2	3	4	5	6
MEAN	4.137	3.573	3.611	3.323	4.290	3.741
(SD)	(1.718)	(0.243)	(0.482)	(0.637)	(1.074)	(0.413)

POSITION	7	8	9	10	11	12
MEAN	4.099	4.782	3.921	3.880	3.239	4.399
(SD)	(0.862)	(1.089)	(0.572)	(0.488)	(1.318)	(1.735)

LOAD = 2

POSITION	1	2	3	4	5	6
MEAN	3.581	3.592	4.109	4.415	4.541	3.594
(SD)	(0.9750	(0.266)	(0.797)	(1.337)	(0.878)	(0.652)

POSITION	7	8	9	10	11	12
MEAN	3.252	4.565	3.918	4.039	4.643	3.912
(SD)	(0.584)	(1.047)	(0.787)	(1.529)	(1.642)	(0.720)

LOAD = 4

POSITION	1	2	3	4	5	6
MEAN	3.075	4.429	4.435	4.805	4.252	3.774
(SD)	(1.136)	(1.024)	(0.767)	(0.571)	(1.161)	(0.562)

POSITION	7	8	9	10	11	12
MEAN	3.580	4.670	4.024	4.047	3.857	2.988
(SD)	(1.027)	(0.879)	(0.858)	(0.851)	(0.746)	(1.171)

YOUNG SUBJECTS
SAME CONDITION
TWO GROUP LISTS
LIST TWO

LOAD = 0

POSITION	1	2	3	4	5	6
MEAN	3.851	3.638	3.666	4.137	4.236	4.971
(SD)	(1.939)	(1.014)	(0.941)	(0.656)	(0.722)	(0.653)

POSITION	7	8	9	10	11	12
MEAN	4.698	3.639	3.641	4.194	3.591	3.795
(SD)	(0.687)	(0.513)	(0.906)	(1.164)	(0.960)	(0.931)

LOAD = 2

POSITION	1	2	3	4	5	6
MEAN	2.923	4.013	3.718	4.486	4.176	3.931
(SD)	(0.875)	(1.091)	(1.727)	(0.681)	(0.663)	(0.378)

POSITION	7	8	9	10	11	12
MEAN	3.809	4.320	4.272	4.360	4.239	3.747
(SD)	(0.744)	(1.690)	(0.666)	(0.760)	(1.070)	(0.686)

LOAD = 4

POSITION	1	2	3	4	5	6
MEAN	3.526	3.842	4.639	4.525	4.845	4.221
(SD)	(1.216)	(1.074)	(0.585)	(0.867)	(1.119)	(1.069)

POSITION	7	8	9	10	11	12
MEAN	3.550	3.369	3.546	4.474	3.817	3.642
(SD)	(0.384)	(0.517)	(0.458)	(1.297)	(0.975)	(1.222)

YOUNG SUBJECTS
SAME CONDITION
TWO GROUP LISTS
LIST FOUR

LOAD = 0

POSITION	1	2	3	4	5	6
MEAN	3.214	3.998	3.710	4.904	3.986	4.554
(SD)	(1.224)	(1.017)	(1.168)	(0.911)	(0.529)	(0.689)

POSITION	7	8	9	10	11	12
MEAN	4.372	3.867	3.884	4.450	4.171	2.887
(SD)	(1.005)	(0.755)	(1.239)	(0.782)	(0.865)	(0.583)

LOAD = 2

POSITION	1	2	3	4	5	6
MEAN	3.484	4.541	3.564	4.564	3.660	4.320
(SD)	(1.664)	(1.172)	(1.605)	(0.865)	(0.952)	(0.722)

POSITION	7	8	9	10	11	12
MEAN	3.852	4.456	4.260	3.935	3.895	3.462
(SD)	(0.596)	(0.725)	(0.790)	(0.715)	(0.710)	(0.850)

LOAD = 4

POSITION	1	2	3	4	5	6
MEAN	3.594	3.692	5.131	4.224	4.639	4.269
(SD)	(1.131)	(0.670)	(0.906)	(0.369)	(0.504)	(0.776)

POSITION	7	8	9	10	11	12
MEAN	4.344	3.744	4.508	3.526	3.201	3.124
(SD)	(4.344)	(3.744)	(4.508)	(3.526)	(0.844)	(1.213)

YOUNG SUBJECTS
ALTERNATING LISTS
THREE GROUP LISTS
LIST TWO

LOAD = 0

POSITION	1	2	3	4	5	6
MEAN	3.766	3.821	3.652	4.475	4.574	4.306
(SD)	(1.206)	(0.776)	(0.427)	(0.985)	(0.885)	(0.889)

POSITION	7	8	9	10	11	12
MEAN	4.418	4.636	3.589	4.081	3.307	3.206
(SD)	(0.726)	(1.386)	(0.656)	(1.034)	(0.836)	(0.940)

LOAD = 2

POSITION	1	2	3	4	5	6
MEAN	3.386	4.308	4.446	3.937	4.100	3.949
(SD)	(1.641)	(0.647)	(1.371)	(1.236)	(0.646)	(1.262)

POSITION	7	8	9	10	11	12
MEAN	4.460	3.973	3.634	4.081	3.826	3.863
(SD)	(0.703)	(0.770)	(0.588)	(0.512)	(0.670)	(1.542)

LOAD = 4

POSITION	1	2	3	4	5	6
MEAN	4.329	4.458	4.646	4.194	4.017	3.956
(SD)	(2.268)	(1.263)	(0.825)	(0.897)	(0.855)	(1.199)

POSITION	7	8	9	10	11	12
MEAN	4.085	3.933	3.494	3.758	3.590	3.534
(SD)	(0.356)	(0.208)	(0.395)	(0.860)	(1.006)	(0.382)

YOUNG SUBJECTS
ALTERNATING CONDITION
THREE GROUP LISTS
LIST FOUR

LOAD = 0

POSITION	1	2	3	4	5	6
MEAN	3.269	3.228	4.156	3.858	4.654	4.580
(SD)	(1.051)	(1.023)	(1.353)	(0.497)	(0.458)	(0.997)

POSITION	7	8	9	10	11	12
MEAN	4.964	3.982	3.649	3.205	4.235	4.214
(SD)	(1.075)	(0.287)	(0.494)	(0.441)	(1.258)	(1.112)

LOAD = 2

POSITION	1	2	3	4	5	6
MEAN	3.386	4308	4.446	3.937	4.100	3.949
(SD)	(1.641)	(0.647)	(1.371)	(1.236)	(0.646)	(1.262)

POSITION	7	8	9	10	11	12
MEAN	4.460	3.973	3.634	4.081	3.826	3.863
(SD)	(0.703)	(0.770)	(0.588)	(0.512)	(0.670)	(1.542)

LOAD = 4

POSITION	1	2	3	4	5	6
MEAN	3.868	4.141	4.647	4.241	3.999	3.755
(SD)	(1.552)	(1.102)	(0.877)	(1.052)	(0.884)	(1.037)

POSITION	7	8	9	10	11	12
MEAN	4.322	3.456	3.723	4.370	3.853	3.621
(SD)	(0.935)	(0.243)	(1.303)	(0.749)	(0.765)	(1.282)

YOUNG SUBJECTS
ALTERNATING CONDITION
TWO GROUP LISTS
LIST TWO

LOAD = 0

POSITION	1	2	3	4	5	6
MEAN	2.690	4.236	4.526	4.225	4.125	4.956
(SD)	(0.8310	(1.405)	(1.369)	(0.658)	(0.748)	(0.994)

POSITION	7	8	9	10	11	12
MEAN	4.486	3.548	3.877	3.629	3.971	3.727
(SD)	(0.886)	(0.636)	(0.785)	(0.259)	(1.063)	(0.661)

LOAD = 2

POSITION	1	2	3	4	5	6
MEAN	2.921	3.728	3.955	3.924	4.345	4.252
(SD)	(1.588)	(0.557)	(0.543)	(0.811)	(0.657)	(1.242)

POSITION	7	8	9	10	11	12
MEAN	4.323	3.993	4.664	3.946	3.817	4.118
(SD)	(1.113)	(0.683)	(1.216)	(0.735)	(1.119)	(1.115)

LOAD = 4

POSITION	1	2	3	4	5	6
MEAN	2.668	4.353	4.344	4.236	4.105	4.122
(SD)	(0.961)	(1.039)	(1.293)	(0.437)	(0.695)	(1.195)

POSITION	7	8	9	10	11	12
MEAN	4.541	4.617	4.196	3.494	3.795	3.522
(SD)	(1.096)	(1.131)	(0.789)	(0.994)	(0.384)	(0.619)

YOUNG SUBJECTS
ALTERNATING CONDITION
TWO GROUP LISTS
LIST FOUR

LOAD = 0

POSITION	1	2	3	4	5	6
MEAN	3.415	4.000	3.990	4.093	4.107	4.191
(SD)	(1.975)	(1.389)	(0.593)	(1.273)	(0.647)	(1.009)

POSITION	7	8	9	10	11	12
MEAN	3.774	4.317	4.465	4.241	3.902	3.501
(SD)	(0.655)	(0.757)	(1.183)	(0.872)	(0.603)	(0.580)

LOAD = 2

POSITION	1	2	3	4	5	6
MEAN	2.429	4.579	3.896	4.613	4.054	3.958
(SD)	(1.204)	(1.385)	(0.912)	(0.886)	(0.576)	(0.809)

POSITION	7	8	9	10	11	12
MEAN	4.355	4.280	4.223	4.287	3.713	3.605
(SD)	(0.609)	(0.785)	(0.568)	(0.995)	(0.862)	(0.932)

LOAD = 4

POSITION	1	2	3	4	5	6
MEAN	2.679	4.209	4.445	3.832	4.084	3.502
(SD)	(1.458)	(0.883)	(0.902)	(0.987)	(0.595)	(0.637)

POSITION	7	8	9	10	11	12
MEAN	4.554	3.909	4.587	3.489	4.883	3.828
(SD)	(0.262)	(0.389)	(0.603)	(0.697)	(1.362)	(1.101)

APPENDIX XXII

MEAN PAUSE TIME AND RECALL MEANS AND STANDARD DEVIATIONS BY DIGIT LOAD

OLD SUBJECTS
SAME CONDITION
THREE GROUP LISTS

LIST = 2

DIGIT LOAD	0	2	4
MPT	2.260	2.687	2.588
(SD)	(0.922)	(1.400)	(1.519)
RECALL	0.958	0.958	0.875
(SD)	(0.102)	(0.102)	(0.209)

LIST = 4

DIGIT LOAD	0	2	4
MPT	2.338	2.967	3.418
(SD)	(0.773)	(1.938)	(3.018)
RECALL	0.667	0.542	0.500
(SD)	(0.438)	(0.292)	(0.474)

OLD SUBJECTS
SAME CONDITION
TWO GROUP LISTS

LIST = 2

DIGIT LOAD	0	2	4
MPT (SD)	3.325 (3.815)	3.138 (2.884)	3.675 (2.561)
RECALL (SD)	0.693 (0.355)	0.777 (0.346)	0.778 (0.201)

LIST = 4

DIGIT LOAD	0	2	4
MPT (SD)	2.528 (1.532)	4.335 (4.841)	3.368 (1.274)
RECALL (SD)	0.945 (0.135)	0.972 (0.069)	0.862 (0.221)

OLD SUBJECTS
ALTERNATING CONDITION
THREE GROUP LISTS

LIST = 2

DIGIT LOAD	0	2	4
MPT	2.497	2.785	4.205
(SD)	(1.041)	(0.921)	(1.136)
RECALL	0.750	0.833	0.875
(SD)	(0.158)	(0.408)	(0.137)

LIST = 4

DIGIT LOAD	0	2	4
MPT	3.227	2.627	3.663
(SD)	(1.153)	(0.888)	(1.435)
RECALL	0.722	0.667	0.750
(SD)	(0.268)	(0.376)	(0.418)

OLD SUBJECTS
ALTERNATING CONDITION
TWO GROUP LISTS

LIST = 2

DIGIT LOAD	0	2	4
MPT	1.993	3.235	3.603
(SD)	(0.618)	(1.365)	(1.046)
RECALL	0.637	0.720	0.610
(SD)	(0.322)	(0.359)	(0.390)

LIST = 4

DIGIT LOAD	0	2	4
MPT	1.840	2.470	3.233
(SD)	(0.770)	(0.497)	(0.747)
RECALL	0.888	0.887	0.833
(SD)	(0.274)	(0.088)	(0.408)

YOUNG SUBJECTS
SAME CONDITION
THREE GROUP LISTS

LIST = 2

DIGIT LOAD	0	2	4
MPT	3.732	3.227	2.092
(SD)	(4.437)	(2.434)	(2.012)
RECALL	1.000	0.958	0.958
(SD)	(0.000)	(0.102)	(0.102)

LIST = 4

DIGIT LOAD	0	2	4
MPT	2.622	3.240	3.778
(SD)	(2.932)	(2.876)	(2.862)
RECALL	0.958	1.000	1.000
(SD)	(0.102)	(0.000)	(0.000)

YOUNG SUBJECTS
SAME CONDITION
TWO GROUP LISTS

LIST = 2

DIGIT LOAD	0	2	4
MPT	1.983	2.213	2.647
(SD)	(0.814)	(0.691)	(1.052)
RECALL	0.835	0.917	0.887
(SD)	(0.181)	(0.139)	(0.088)

LIST = 4

DIGIT LOAD	0	2	4
MPT	2.138	1.950	2.387
(SD)	(0.806)	(1.122)	(0.917)
RECALL	0.888	0.807	0.860
(SD)	(0.136)	(0.221)	(0.125)

YOUNG SUBJECTS
ALTERNATING CONDITION
THREE GROUP LISTS

LIST = 2

DIGIT LOAD	0	2	4
MPT (SD)	1.517 (0.448)	2.163 (0.771)	2.698 (1.512)
RECALL (SD)	1.000 (0.000)	0.875 (0.137)	0.875 (0.209)

LIST = 4

DIGIT LOAD	0	2	4
MPT (SD)	1.683 (0.679)	2.247 (0.462)	2.475 (1.474)
RECALL (SD)	0.875 (0.209)	0.875 (0.209)	0.917 (0.129)

YOUNG SUBJECTS
ALTERNATING CONDITION
TWO GROUP LISTS

LIST = 2

DIGIT LOAD	0	2	4
MPT (SD)	2.022 (1.106)	2.305 (1.033)	2.770 (1.426)
RECALL (SD)	1.000 (0.000)	0.888 (0.202)	0.915 (0.093)

LIST = 4

DIGIT LOAD	0	2	4
MPT (SD)	1.790 (0.465)	2.403 (1.354)	2.193 (1.144)
RECALL (SD)	0.972 (0.069)	0.860 (0.125)	0.888 (0.136)

APPENDIX XXIII

CONTRAST ANALYSES OF SIX BLOCK PATTERNS

SAME CONDITION
THREE GROUP LISTS
OLD SUBJECTS

SOURCE	DF	SS	MS	F
BLOCK 1 v. BLOCK 2/	2/	1.878	0.939	2.96
POS*SN(AGE*SD*AB)	10	3.173	0.317	
BLOCK 2 v. BLOCK 3/	2/	14.602	7.301	16.90*
POS*SN(AGE*SD*AB)	10	4.320	0.432	
BLOCK 3 v. BLOCK 4/	2/	1.024	0.512	1.11
POS*SN(AGE*SD*AB)	10	4.611	0.461	
BLOCK 4 v. BLOCK 5/	2/	0.0	0.0	< 1.0
POS*SN(AGE*SD*AB)	10	3.090	0.309	
BLOCK 5 v. BLOCK 6/	2/	2.784	1.392	2.22
POS*SN(AGE*SD*AB)	10	6.283	0.628	
BLOCKS 1&3 v. BLOCK 2/	2/	7.496	3.748	10.90*
POS*SN(AGE*SD*AB)	10			
BLOCKS 2&4 v. BLOCK 3/	2/	13.001	6.500	13.51*
POS*SN(AGE*SD*AB)	10	4.814	0.481	
BLOCKS 3&5 v. BLOCK 4/	2/	0.672	0.336	1.09
POS*SN(AGE*SD*AB)	10	3.080	0.308	

* - *p* <.05

SAME CONDITION
THREE GROUP LISTS
YOUNG SUBJECTS

SOURCE	DF	SS	MS	F
BLOCK 1 v. BLOCK 2/	2/	5.360	2.680	3.33
POS*SN(AGE*SD*AB)	10	8.062	0.806	
BLOCK 2 v. BLOCK 3/	2/	0.785	0.393	< 1.0
POS*SN(AGE*SD*AB)	10	4.810	0.481	
BLOCK 3 v. BLOCK 4/	2/	5.684	0.284	< 1.0
POS*SN(AGE*SD*AB)	10	3.436	0.344	
BLOCK 4 v. BLOCK 5/	2/	0.046	0.023	< 1.0
POS*SN(AGE*SD*AB)	10	3.529	0.353	
BLOCK 5 v. BLOCK 6/	2/	0.044	0.022	< 1.0
POS*SN(AGE*SD*AB)	10	6.877	0.688	
BLOCKS 1&3 v. BLOCK 2/	2/	2.728	1.364	2.23
POS*SN(AGE*SD*AB)	10	6.130	0.613	
BLOCKS 2&4 v. BLOCK 3/	2/	1.351	0.675	2.17
POS*SN(AGE*SD*AB)	10	3.109	0.311	
BLOCKS 3&5 v. BLOCK 4/	2/	0.520	0.260	< 1.0
POS*SN(AGE*SD*AB)	10	3.705	0.371	

* - $p < .05$

SAME CONDITION
TWO GROUP LISTS
OLD SUBJECTS

SOURCE	DF	SS	MS	F
BLOCK 1 v. BLOCK 2/	2/	5.100	2.550	1.55
POS*SN(AGE*SD*AB)	10	16.482	1.648	
BLOCK 2 v. BLOCK 3/	2/	0.512	0.256	< 1.0
POS*SN(AGE*SD*AB)	10	4.841	0.484	
BLOCK 3 v. BLOCK 4/	2/	0.158	0.079	< 1.0
POS*SN(AGE*SD*AB)	10	12.460	1.246	
BLOCK 4 v. BLOCK 5/	2/	0.134	0.067	< 1.0
POS*SN(AGE*SD*AB)	10	8.351	0.835	
BLOCK 5 v. BLOCK 6/	2/	3.171	1.585	2.47
POS*SN(AGE*SD*AB)	10	6.424	0.642	
BLOCKS 1&3 v. BLOCK 2/	2/	4.820	2.410	1.80
POS*SN(AGE*SD*AB)	10	13.381	1.338	
BLOCKS 2&4 v. BLOCK 3/	2/	0.256	0.128	< 1.0
POS*SN(AGE*SD*AB)	10	12.854	1.285	
BLOCKS 3&5 v. BLOCK 4/	2/	0.292	0.146	< 1.0
POS*SN(AGE*SD*AB)	10	11.021	1.102	

* - $\underline{p} < .05$

SAME CONDITION
TWO GROUP LISTS
YOUNG SUBJECTS

SOURCE	DF	SS	MS	F
BLOCK 1 v. BLOCK 2/	2/	12.082	6.041	5.70*
POS*SN(AGE*SD*AB)	10	17.807	1.781	
BLOCK 2 v. BLOCK 3/	2/	0.072	0.036	< 1.0
POS*SN(AGE*SD*AB)	10	10.134	1.013	
BLOCK 3 v. BLOCK 4/	2/	3.588	1.794	1.91
POS*SN(AGE*SD*AB)	10	9.369	0.937	
BLOCK 4 v. BLOCK 5/	2/	0.264	0.132	< 1.0
POS*SN(AGE*SD*AB)	10	1.569	0.157	
BLOCK 5 v. BLOCK 6/	2/	7.500	3.750	9.84*
POS*SN(AGE*SD*AB)	10	3.808	0.381	
BLOCKS 1&3 v. BLOCK 2/	2/	8.728	4.364	3.05
POS*SN(AGE*SD*AB)	10	14.334	1.433	
BLOCKS 2&4 v. BLOCK 3/	2/	2.100	1.050	1.24
POS*SN(AGE*SD*AB)	10	8.437	0.844	
BLOCKS 3&5 v. BLOCK 4/	2/	1.918	0.959	3.17
POS*SN(AGE*SD*AB)	10	3.031	0.303	

* - $p < .05$

ALTERNATING CONDITION
THREE GROUP LISTS
OLD SUBJECTS

SOURCE	DF	SS	MS	F
BLOCK 1 v. BLOCK 2/	2/	0.166	0.083	< 1.0
POS*SN(AGE*SD*AB)	10	15.721	1.512	
BLOCK 2 v. BLOCK 3/	2/	0.036	0.018	< 1.0
POS*SN(AGE*SD*AB)	10	2.710	0.271	
BLOCK 3 v. BLOCK 4/	2/	0.250	0.125	< 1.0
POS*SN(AGE*SD*AB)	10	5.984	0.598	
BLOCK 4 v. BLOCK 5/	2/	0.638	0.319	< 1.0
POS*SN(AGE*SD*AB)	10	4.651	0.465	
BLOCK 5 v. BLOCK 6/	2/	3.408	1.704	54.97*
POS*SN(AGE*SD*AB)	10	0.311	0.031	
BLOCKS 1&3 v. BLOCK 2/	2/	0.082	0.041	< 1.0
POS*SN(AGE*SD*AB)	10	9.542	0.954	
BLOCKS 2&4 v. BLOCK 3/	2/	0.256	0.128	< 1.0
POS*SN(AGE*SD*AB)	10	6.444	0.644	
BLOCKS 3&5 v. BLOCK 4/	2/	0.860	0.430	< 1.0
POS*SN(AGE*SD*AB)	10	4.978	0.498	

* - $p < .05$

ALTERNATING CONDITION
THREE GROUP LISTS
YOUNG SUBJECTS

SOURCE	DF	SS	MS	F
BLOCK 1 v. BLOCK 2/	2/	4.534	2.267	5.77*
POS*SN(AGE*SD*AB)	10	3.934	0.393	
BLOCK 2 v. BLOCK 3/	2/	0.006	0.003	< 1.0
POS*SN(AGE*SD*AB)	10	9.427	0.943	
BLOCK 3 v. BLOCK 4/	2/	0.056	0.028	< 1.0
POS*SN(AGE*SD*AB)	10	8.679	0.868	
BLOCK 4 v. BLOCK 5/	2/	8.026	4.013	12.35*
POS*SN(AGE*SD*AB)	10	3.251	0.325	
BLOCK 5 v. BLOCK 6/	2/	0.086	0.043	< 1.0
POS*SN(AGE*SD*AB)	10	5.812	0.581	
BLOCKS 1&3 v. BLOCK 2/	2/	2.914	1.457	2.00
POS*SN(AGE*SD*AB)	10	7.281	0.728	
BLOCKS 2&4 v. BLOCK 3/	2/	0.028	0.014	< 1.0
POS*SN(AGE*SD*AB)	10	10.701	1.070	
BLOCKS 3&5 v. BLOCK 4/	2/	4.941	2.470	3.06
POS*SN(AGE*SD*AB)	10	8.084	0.808	

* - $p < .05$

ALTERNATING CONDITION
TWO GROUP LISTS
OLD SUBJECTS

SOURCE	DF	SS	MS	F
BLOCK 1 v. BLOCK 2/	2/	0.304	0.152	< 1.0
POS*SN(AGE*SD*AB)	10	11.391	1.139	
BLOCK 2 v. BLOCK 3/	2/	0.240	0.120	< 1.0
POS*SN(AGE*SD*AB)	10	5.218	0.522	
BLOCK 3 v. BLOCK 4/	2/	1.001	0.500	2.37
POS*SN(AGE*SD*AB)	10	2.105	0.211	
BLOCK 4 v. BLOCK 5/	2/	6.118	3.059	11.21*
POS*SN(AGE*SD*AB)	10	2.730	0.273	
BLOCK 5 v. BLOCK 6/	2/	0.024	0.012	< 1.0
POS*SN(AGE*SD*AB)	10	2.128	0.213	
BLOCKS 1&3 v. BLOCK 2/	2/	0.182	0.091	< 1.0
POS*SN(AGE*SD*AB)	10	9.127	0.913	
BLOCKS 2&4 v. BLOCK 3/	2/	1.154	0.577	1.19
POS*SN(AGE*SD*AB)	10	4.839	0.484	
BLOCKS 3&5 v. BLOCK 4/	2/	6.398	3.199	14.67*
POS*SN(AGE*SD*AB)	10	2.181	0.218	

* - $p < .05$

ALTERNATING CONDITION
TWO GROUP LISTS
YOUNG SUBJECTS

SOURCE	DF	SS	MS	F
BLOCK 1 v. BLOCK 2/	2/	16.654	8.327	7.86*
POS*SN(AGE*SD*AB)	10	10.604	1.060	
BLOCK 2 v. BLOCK 3/	2/	0.018	0.009	< 1.0
POS*SN(AGE*SD*AB)	10	11.311	1.131	
BLOCK 3 v. BLOCK 4/	2/	0.198	0.099	< 1.0
POS*SN(AGE*SD*AB)	10	5.614	0.561	
BLOCK 4 v. BLOCK 5/	2/	0.638	0.319	< 1.0
POS*SN(AGE*SD*AB)	10	5.200	0.520	
BLOCK 5 v. BLOCK 6/	2/	1.842	0.921	1.13
POS*SN(AGE*SD*AB)	10	8.161	0.816	
BLOCKS 1&3 v. BLOCK 2/	2/	10.738	5.369	3.39
POS*SN(AGE*SD*AB)	10	15.864	1.586	
BLOCKS 2&4 v. BLOCK 3/	2/	0.104	0.052	< 1.0
POS*SN(AGE*SD*AB)	10	7.671	0.767	
BLOCKS 3&5 v. BLOCK 4/	2/	0.320	0.160	< 1.0
POS*SN(AGE*SD*AB)	10	8.560	0.856	

* - p <.05

GRADUATE SCHOOL
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DISSERTATION APPROVAL FORM

Name of Candidate Thomas F. Bergquist

Major Subject Medical Psychology

Title of Dissertation Age-Related Differences in Memory: The Role of the Executive

Dissertation Committee:

Linda W. Duke, Chairman

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