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Adult age differences in working memory and speech production: Preservation and loss in normal aging

Lahar, Cindy Jeanne, Ph.D.

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U·M·I
300 N. Zeeb Rd.
Ann Arbor, MI 48106

ADULT AGE DIFFERENCES IN WORKING MEMORY AND SPEECH PRODUCTION: PRESERVATION AND LOSS IN NORMAL AGING

by

CINDY JEANNE LAHAR

A Dissertation

Presented to the Faculty of the Graduate School of Arts and Sciences
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ABSTRACT

Adult Age Differences in Working Memory and Speech Production: Preservation and Loss in Normal Aging

(A Dissertation Presented to the
Faculty of the Graduate School of Arts and Sciences of
Brandeis University, Waltham, Massachusetts)

by Cindy J. Lahar

Producing language must involve *working memory*, hence it is predicted that a reduction in the capacity of working memory that occurs in elderly adults will lead to changes in the quality or quantity of spoken language. An age-related decline in working memory capacity has been implicated in the older adults' decreased abilities to remember spoken discourse. There is, however, no data examining whether a decrease in working memory capacity will affect the production of language, in fact, very little research has been done on the changes that occur with age in spoken language.

To examine working memory and language production, a dual task paradigm was used with young and old groups. Past research with young adults has found that concurrent activity (e.g., recall of digit strings) affects the time needed to formulate a sentence from two words (Power, 1985). This thesis includes a study in which young and old subjects had a memory pre-load of random digit lists while creating sentences from visually presented noun pairs. The noun pairs were either highly related or unrelated (e.g., uncle-aunt vs. baby-dust). Additionally, eight different memory tests were administered: three measured simple storage capacity, and five

measured working memory capacity.

When subjects were required to concurrently hold lists of random digits in memory during sentence generation, all groups produced shorter and less informative sentences. Contrary to expectations, this was not especially the case for the elderly. The elderly consistently remembered less than the young in each of the eight memory tests; interestingly, this age difference was not especially pronounced in the working memory tests. It appears that working memory loading does not lead to a differential disadvantage for the elderly in either the working memory span tests or in the dual task testing situation.

All subjects formulated more complex sentences from the unrelated word pairs than from the related pairs. When there was no concurrent task, the elderly generated more informative sentences than the young adults. This finding suggests that some aspects of the language production system remain relatively stable, or improve in advanced years.

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CHAPTER 1
Introduction

Every day we take in and act on information in countless ways. Our memory systems are necessary for almost every task we engage in - tasks such as the production and comprehension of language, object recognition, problem solving and decision making. In fact, any system, such as the human processing system must be able to store and process information in order to learn.

We communicate verbal information in three possible ways: we speak, we write or we tap on a keyboard.[1] Speaking is an integral part of our normal and everyday world, and it is crucial that the speaker is successful in conveying his or her wishes, needs and desires. Individuals of all ages relate stories to each other, tell of events of the day, request information verbally, plan trips and social events. Successful language comprehension and production are a prerequisite for effective communication - the very foundation of our social interactions. "Please pass the salt"; "I need a ride to work at 8 a.m."; "Andrea and Greg are getting married"; "The square of the hypotenuse of any right triangle is equal to the sum of the squares of the other two sides." It is necessary to both produce and comprehend ideas for any meaningful communication to occur.

Speaking is one of the most complex skills, yet we are highly complex information processors. We can transform thoughts, intentions and feelings into fluently articulated speech.

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[1] I exclude from this discussion the use of sign language by the deaf; although many of the properties of spoken language to be discussed here have temporal counterparts in sign language production (Grosjean & Lane, 1981).

There are times however, when speech production processes can be perturbed. In real world situations, it is undoubtably the case that processing demands on working memory (WM) fluctuate during speech production. Take for example, the case when conversing in a car: sudden hazardous conditions consistently result in the driver halting the conversation (and if necessary, the car).

In everyday speech, the speaker is often required (or chooses) to perform an additional task. All too rarely do we have the luxury of sitting down and pouring all of our attention into the conversation at hand. It is much more frequent to find ourselves devoting only a portion of our available capacity to a conversation. How often have you found yourself amidst a crowd discussing what to select for lunch. Remember the last time you looked up a phone number and forgot it as you answered someone's question? Maybe it was even worse; you were mid-sentence and a distraction led you to forget what you were talking about. Both production and comprehension of speech is likely to be perturbed by concurrent tasks. Furthermore, it is often the case that short term memory failures occur due to simultaneous activity.

Sometimes a secondary task may be very difficult and sometimes it may be less strenuous to the language production system used by the speaker. One possible way to look at allocation of resources is to use a divided attention, or dual, task. The notion of dual task, or doing more than one thing at a time, will be incorporated into the experimental methods of the research presented in this thesis. The dual task technique assumes limited capacity which may be allocated flexibly between processing and storage demand (e.g. Baddeley & Hitch, 1974; Kahneman, 1973; Navon & Gopher, 1979).

One way in which demands made by speech planning can be investigated is through the loading of WM with a secondary task. Working memory can be considered one's mental chalkboard, or mental desk. Indeed it is assumed that speech production processes make use of this general workspace or WM. So we can examine speech production and processing under varying loads of task difficulty. There is always an associated cost with doing two things at once. Increasing incrementally the difficulty of one task can serve to decrease performance on the other task.

Since it is assumed that speech production processes make use of a general workspace or working memory, then the planning of speech necessitates that workspace must be available for both the formulation of an intention and the realization of that intention as a sequence of words or sounds. WM must be flexible enough to be distributed between the processing and storage demands of speech and any other activities in which a speaker is engaged (Power, 1985; Levelt, 1989).

The use of a memory pre-load of random digit-lists has been used extensively as a secondary task (Baddeley & Hitch, 1974; Hitch, 1980; Hitch, 1984). Furthermore, it has been shown for young adults that a memory pre-load affects latencies to generating sentences from two presented nouns (Power, 1985). Whether a secondary task such as this is more or less damaging to the speech output produced by an elderly person compared to their younger counterpart is an important question for the fields investigating cognitive processes and cognitive aging. Very little research has been done on the dynamics of conversation change with age (Spilich, 1985).

As we shall see, an older adult's performance on speech recognition, recall and production is often indistinguishable from that of a younger counterpart. But if this is attributable to top-down or knowledge driven resources, there may be a greater drain on the limited capacity system of the elderly adult. This is hypothesized to be the case because of considerable evidence that the elderly adult has a greater limitation on immediate memory capacity. If older adults are limited in their processing capacity, they would have to devote a greater proportion of their resources to maintain a good level of performance on the primary task - and we would expect larger age differences in cognitive performance with increasing demands. It has been reported that the inadequacy of the older adults' processing resources may only be exposed when the memory load placed on them is high (Cohen, 1988).

Many researchers have investigated age related changes in capacity demands as a function of task complexity. Craik and Byrd (1982) proposed that a reduction in attentional capacity might serve as the explanation for the fact that elderly adults do not tend to engage in deeper levels of processing. Furthermore, certain studies of adult language conclude that linguistic skills deteriorate with old age (e.g., Albert, 1981; Kemper, 1988). However, language and memory do not decline uniformly in old age, some aspects of each are impaired while some remain spared (Light & Burke, 1988).

There has been a considerable amount of research on language comprehension and recall in aging. When deficits do occur, they are most often attributed to mediating factors such as memory limitations, a slowing in processing rate, or to limitations in attentional resources (see Light & Burke, 1988). The production of language might also be presumed to be mediated by these factors, yet the evidence and research on this topic is at a bare minimum (Light, 1988). Overall, the question of language production is by far less studied than that of language comprehension (Klatzky, 1988). The speech production of older adults has been hypothesized to be particularly vulnerable to high processing demands. Specifically, the variable of complexity in sentence production places a load on memory (Klatzky, 1988; Kemper, 1988). Along with the hypothesis that WM capacity is reduced with age (Wingfield, Stine, Lahar & Aberdeen, 1988) it is expected that fluent speech production in the elderly may be differentially hurt by increasing the load on working memory.

There is some evidence that memory limitations in old age may affect speech production processes. Walker, Roberts and Hedrick (1988) report supportive evidence in that the older adults produce shorter utterances in comparison to a young group, and Kynette and Kemper (1986) report that older adults produce less syntactically complex utterances. These findings suggest that the speech production of older adults has some fundamental differences from the speech of young adults, which may be mediated by memory limitations.

The hypothesis that the elderly have reduced working memory capacity predicts that there would be an increase in planning time associated with speech for the elderly in relation to the young. There has been no data to support or deny this prediction (Light, 1988). In fact, the available data on speech production and aging leaves many hypotheses untested (see Light, 1988, p196-197).

One of the most fascinating questions is how humans communicate, and hence, the relation of language, memory and thought. This is evident from the tremendous amount of current interest in these relations by linguists, psychologists and neuropsychologists alike. One way to investigate this question is to examine whether there are any changes that occur across the lifespan. Does aging affect the ability to communicate ?

This thesis includes a study in which three groups of subjects had a memory pre-load of random digit-lists while making up sentences from visually presented noun pairs. These nouns pairs were either highly related or unrelated. As we produce speech, it is necessary to hold words in working memory, establish a relationship, construct a sentence and output that sentence. If it is the case that the older adults have working memory limitations and if complexity adds to the burden, then we would expect to find a differential reduction in the quantity or the quality of speech produced under memory load.

This research will examine age-related changes in the processes involved in speech production. The study presented looks at the output side of processing by studying young and old adults' sentence production in a dual-task paradigm. The findings have implications for the everyday speech of elderly adults when it is produced while performing a cognitively complex secondary task.

This thesis will include a presentation of the general concept of working memory, and a discussion of the influence that working memory may have on an everyday task such as speech production. Chapter 2 introduces the concept of working memory, and provides a selection of current models of working memory. Chapter 3 discusses the cognitive limitations associated with aging, and directly asks the question: Is there a reduced capacity of working memory with age? Chapter 4 will discuss what is involved with the production of speech. Chapter 4 will also discuss the role of the working memory system in language production. Also, an extension of what we know about aging will be developed in relation to speech production processes. Throughout these chapters, the goal will be to center on aspects of the human information processing system that rely on a working memory system, while providing the reader with an overview of the literature and the concerns in the field today.

Chapter 5 will present an experiment designed to address these (and other) concerns. Chapter 7 provides a re-analysis of some of the data provided in Chapter 6 in order to investigate some methodological issues relevant to cognitive aging research. Finally, Chapter 8 will serve to integrate the findings presented here with those of other researchers and to draw some general conclusions.

CHAPTER 2
Working Memory

Working memory (WM) has been compared to a sort of mental chalkboard, a limited capacity system for holding and manipulating information (e.g. Hitch, 1980; Baddeley,1981; Monsell, 1984). It has been suggested that some reduction in the capacity of working memory may also serve to explain some of the deficits that accompany normal aging (e.g. Craik & Simon, 1980 ; Gick, Craik & Morris, 1988 ; Morris, Gick & Craik, 1988; Stine & Wingfield, 1987). This chapter will discuss both the development of the concept of WM, and the current formulations of the WM model. Chapter 3 will discuss the possibility of a specific decrease in WM with age. Chapter 4 will extend this discussion of working memory and aging to the realm of speech production.

An example to ponder, or hold in WM

"I was going to take a train to New York, but I was afraid it would be too heavy".

In order for us to understand this sentence, it is absolutely necessary to have a working memory system. The reader or listener, in any situation, must have access to what has previously been read/heard in order to parse, disambiguate or simply comprehend this relatively simple sentence. Consider what is necessary in the case of listening to a sentence like this: the listener must hear and comprehend *I was going to take a train to New York,* hold this in some active processing state, and concurrently listen to, and comprehend, *But, I was afraid it would be too heavy*. At that point, the listener must connect this second portion of the sentence to that previous portion currently active in WM. Each of these steps is necessary in order to both understand the sentence, and realize that it is a joke. Furthermore, some people may retrieve from their long term memory system that this particular line is a Groucho Marx classic. This combination of activation of data from bottom-up data driven sources (the sentence itself) and of top-down sources (the memory or knowledge of Groucho Marx telling this joke; knowledge about the extreme weight of a train, knowledge about travel) is necessary for comprehension. This example provides a flavor for the working memory model.

The History of Working Memory

Since the 1950's there have been numerous formulations or models proposed to explain immediate or short term memory (STM). In his classic paper, George Miller (1956) proposed a capacity limitation on STM in terms of the Magical Number 7 ± 2. Soon to follow, Broadbent (1957) and later Atkinson and Shiffrin (1968) delineated structural information processing models of memory.

Structural formulations of memory consider memory in terms of discrete mechanisms. However, the 1970's brought various criticisms of the structural formulation or "modal model" of memory. For example, it was then that theorists realized that STM capacity is more variable than Miller suggested. Not only is it often cited that individuals can remember much more than 5 - 9 items (especially if properly "chunked"), but many real world tasks could not be accomplished if our capacities of short term-storage were only 5 -9 items. For example, a sentence that includes many more than ten words is still relatively easy to recall shortly after hearing it.

Additionally, the importance of 'processing' as opposed to structure became apparent.

Craik and his colleagues (Craik & Lockhart, 1972; Craik and Tulving, 1975) introduced in the early 1970's the *Levels of Processing* framework for memory. In general, the multiplicity of the human information processing system could no longer be accounted for by a rather simple dichotomy of short and long term memory. Simple storage and rehearsal mechanisms no longer could adequately account for the human processing systems' short term memory abilities.

The term *working memory* (WM) was first brought to the field of psychology by Alan Baddeley and Graham Hitch (1974). These researchers set out to determine the function of short-term memory. In doing so, they postulated that there was more than a single structure to STM, that is, it was no longer an adequate description to think of STM as a single "box" with a limited capacity and fixed duration. Their introduction of the WM model defined working memory as a limited capacity system with the functions of holding information and manipulating that information. Baddeley and Hitch (1974; and see Baddeley 1981) later expanded on the notion of WM, providing a framework for a more detailed description of the model. They subdivided WM into three components, that of two separate passive systems for the storage of different types of materials, and a *central executive* that operates as a control processor. The two storage systems are the *visual-spatial scratchpad*, and the *articulatory loop*. This description of working memory will be detailed in the next section.

Baddeley's Working Memory Model

The heart of the working memory model is the *central executive*. It's function is to integrate information from the two passive storage systems and from long term memory. In essence, it's role is that of the attentional mechanism. It is not modality specific and is available for such tasks as general problem-solving. It is the central switchboard of the human cognitive system. It is a region of temporary memory which would be subject to interference from processing in general.

The *articulatory loop* is responsible for all speech based information. Often it is talked about as a limited capacity phonological store, for it is assumed to have a phonological code. Initially this loop was formulated as a slave system component of the WM model that functions like a limited duration tape loop, assumed to be 1.5 seconds in length (Baddeley & Hitch, 1974). It's responsibilities included holding speech based material in temporary storage and maintaining that information by means of rehearsal. Postulation of this loop turned out to account for a wide range of short term memory phenomena.

Findings such as the phonological similarity effect and the word length effect were easily explained by the articulatory loop. The *phonological similarity effect* refers to the fact that words or letters that sound alike are more easily confused and are more likely to cause confusions in recall than are words that look alike or have a similar meaning. That is, visual similarity and semantic similarity do not have such a strong impact on confusion errors in recall. Initially, these findings were taken as support for the notion that the short-term memory store relies on acoustical storage codes, but these results are equally interpretable as support for an articulatory loop.

The *word length effect* refers to the fact that memory span for short words is greater than it is for long words. That is, the articulatory loop will hold fewer longer words. In Baddeley's terms, the loop can fit more shorter words on it than it can longer words. Memory performance for words then, is based simply on the duration of the spoken words.

Finally, *articulatory suppression* studies were also supportive of an articulatory loop. Studies of articulatory suppression involve requiring a subject to utter some irrelevant sounds or words during an immediate recall task. Recall performance is impaired when articulatory suppression is required. The assumption is that if the articulatory loop is currently filled with some items being rehearsed, then new items will only be able to enter the loop if there is extra space.

Although the initial formulation of the loop was postulated to be 1.5 seconds in length, the revised model made a distinction between a phonological store and an articulatory rehearsal process (Baddeley, Lewis & Vallar, 1984; Salame & Baddeley, 1982). In this adaption, material can enter the store via an obligatory process of auditory presentation or an optional process of articulatory rehearsal. This new formulation can reconcile findings such as the existence of the phonological similarity effect even with articulatory suppression. It is consistent with the notion that auditory presentation guarantees access to a phonological store, and indeed it is the case that when we hear language in our environment, we can not help but understand what is said.

The *visual spatial scratchpad* is the second storage component of Baddeley's WM model. It is capable of creating and manipulating visual images. It is evident that imagery is important in memory. This scratchpad will allow for visual encoding of stimuli in the environment, and many mnemonic methods of remembering make use of this important feature of the system.

Baddeley examined the role of working memory by requiring people to perform irrelevant tasks such as remembering digit lists while simultaneously performing another task (Baddeley & Hitch, 1974; Baddeley, 1986; Hitch, 1984). The assumption is that if digits occupy a common WM, they will interfere with the task at hand. This method of examining WM allows the investigator to consider performance during on-line cognitive tasks. This methodological aspect of the working memory model will be explored in the experiment described in this thesis (see Chapter 5.).

Domain Specific Models of Working Memory

Certainly Baddeley's notion of WM incorporates domain specificity; that is, he delineates two separate domain specific areas which store information, a visual and an articulatory area. However, other theorists push this point of domain specificity much further (Barnard, 1985; Monsell, 1984; Schneider and Detweiler, 1987).

Monsell (1984) assumes that cognitive processing is modular and distributed over autonomous subsystems. These subsystems are connected by belonging to the general cognitive system. With this stance comes the view that WM is a term that describes various distributed specialized storage capacities. The advantage of a model such as this is that it is no longer necessary to include a central or general purpose storage capacity (such as Baddeley's central executive). Monsell discusses two types of temporary storage, one being persistent activation. In a sense this would be "the currently activated subset of preexisting memory structures" (p. 332). The other method of temporary storage accounts for how we can represent novel structure. This, in principle, could encode anything at all. According to Monsell, this encoding of novel events will take the form of either 1) replicating attributes pulled from permanent storage to the active "representational space", or 2) by adding new relations or new labels to preexisting structures in memory.

Schneider and Detweiler (1987) also consider a modular scheme, which they have formulated in a computer systems approach. The architecture that these researchers propose for WM include resources such as buffer regions, and a control structure with connection weights. Their model stresses a competition for the control structure. They propose several accounts of how this competition might occur and in some cases, be reduced.

Schneider and Detweiler postulate five strategies for performance on concurrent tasks. One time sharing strategy is to perform one task and then the other. Here, for example, we would expect an increase in reaction time on one or both tasks due to time sharing. A second strategy would be to make use of buffers not generally used in the task at hand. This would theoretically allow performance to remain undisturbed due to the use of new or separate systems. They cite Baddeley's work by noting that a small digit load (1-3 items) produces no change in the accuracy or speed of processing on a simultaneous task. On the other hand, a large digit-load will exceed the capacity of the buffer, and therefore increase reaction time and possibly errors in the primary task.

A third strategy is a context-storage strategy, involving the use of context to aid in loading modules under high workload situations. A fourth strategy is to develop automatic processes in order to reduce cognitive load. That is, a frequently used process or message can be eventually automated, and therefore if automatically processed, will no longer impinge on the control resources.

The final strategy they offer is to reduce interference resulting from concurrent messages. Practice may be on way of accomplishing this, such as the case of the expert typist. Expert typists become easily able to handle typing and conversing simultaneously. According to Schneider and Detweiler, the expert case is explained by a change in connection weights. For the case of the expert typist then, the strategy would be to strengthen visual to motor connections, and to weaken the visual to semantic connections. This would result in less interference. This notion is identical to Monsell's notion of decoupling subsystems (1984), which he explains as a process of inhibiting communication between subprocessors in the case of task conflict. However, Monsell notes that some systems can be decoupled and others can not (p.347) where Schneider and Detweiler do not pose this constraint.

Although these theoretical notions are appealing, there has been very little human performance data on the relationships among a variety of working memory measures that tap different domains. Researchers tend to use one (or two) tests of working memory within a single domain. Currently, more research is necessary in order to establish relationships among (or existence of) a set of "working memories". Similarly, more research is needed to assess the current state of the different memory span tests we have available to test working memory.

Assessing Working Memory

At this point in time, WM has been studied extensively in a variety of paradigms, in a variety of preparations or systems, and across a wide range of fields. As theorists postulate the influence of WM on various cognitive tasks, or the implications of a decrease in WM with age, an important question then becomes: How can we measure WM?

Any measure of WM must incorporate a storage component and a processing component. Perhaps the most widely used method of testing WM is to collect both forward and backward digit spans from a person. The forward digit span test involved listening to progressively longer lists of random numbers, and simply recalling them back. This test certainly taps storage, but requires very little processing. The backwards digit span requires the numbers to be reported back in the reverse order of the original list, and therefore requires both a storage and manipulation of these numbers simultaneously. By administering both of the measures, it is assumed that the forward span then gives a score that represents immediate storage capacity. The backward span, on the other hand, represents the abilities of the working memory system.

Generally, this method of measuring WM has met with little success. If we assume that the older adult has a smaller WM than a young adult, then a test of the adequacy of the forward-backward digit span testing method would be to find a differential decrease in scores for the older adult on the backward digit span. Babcock and Salthouse (1990) reviewed a number of studies that used the forward and backward digit span testing method in young and old adults. They found that there was, on average, no differential decrease among these two digit span scores for the older adult as compared to the young. One interpretation of this finding is that these spans do not adequately assess a storage (forward digit span) and a separate WM component (backward digit span).

Meredith Daneman (Daneman & Carpenter, 1980; Daneman, Carpenter & Just, 1982; Daneman & Greene, 1986; Daneman & Tardif, 1987) has done a great deal of research on the concept of WM in relation to reading. Her main assumption is that individual differences in reading ability arise mainly from differences in the efficiency or capacity of working memory. The key to this finding was the reading span test pioneered by Daneman and her colleagues.

Daneman and Carpenter (1980) asked subjects to read an ordinary text while remembering the last word of each sentence. After a set of sentences, they were required to recall the last words of those sentences. Thus someone reading the previous paragraph would have to remember the words *reading, memory* and *colleagues.* The goal was to find a measure of overall operational capacity, some quantity that would encompass both storage capacity and processing power. People do vary on performance in this reading span task, and those with high span measures read faster than their low span counterparts. High span people also scored higher on tests of reading comprehension. Furthermore, the reading span measure has been claimed to be one of the best predictors of reading comprehension ever found (Baddeley, Logie, Nimmo-Smith & Brereton, 1985; Daneman & Carpenter, 1980; Daneman, Carpenter & Just, 1982; Waldrop, 1987).

The predictability of reading abilities from a 'reading' WM test has led to a search for WM tests that are predictive of other aspects of cognitive performance. The success of the venture has thus far been disappointing. Tests such as the backward digit span and the reading span are what Salthouse (1990) has recently termed "out-of-context" assessments of WM. *Out-of-context* tests are measures that are obtained in a task deliberately designed to assess memory capacity. He offers the term *in-context* to describe measures of working memory obtained during the performance of an actual on-going cognitive task. Many of Baddeley's studies involving pre-loads of the memory system (with random numbers or letters) during cognitive performance would be examples of in-context tests of WM (Baddeley, 1986).

Researchers have designed a variety of WM tests, and it appears that each investigator has their own 'pet' tests that they include as measures of WM capacity or efficiency. The problem is that it is rare to find any data on the relationship among the tests used by different researchers. Furthermore, clear agreement, as well as empirical evidence, is lacking on what these tests actually measure. Are all working memory tests measuring a common construct, or is each test measuring a separate domain? The second point suggests that each domain will have separate processing capabilities. The fact that the reading span test is predictive of reading abilities but not of spatial or listening abilities suggests this is so. Monsell's (1984) theoretical stance would be supported with similar findings in other domains. However, besides the reading span, there is very little evidence that tests are particularly predictive of performance in one domain or another. In fact, the tests that are available are not necessarily predictive of performance for many of the tasks we might expect.

The question of finding a test that appropriately tests working memory capacity and/or efficiency is still not answered today. Finally, the relationships between in-context and out-of-context tests of WM have not been established (Salthouse, 1990). That is, it is important to determine whether the measures acquired from within a cognitive performance task relate to those that are designed specifically to tap working memory.

CHAPTER 3
Working Memory and Age

Introduction

With age come certain detrimental changes in our abilities to process information. Age differences in memory performance involve a complex set of interactions, dependent at least on the abilities of the subjects tested, the tasks employed and the materials used (e.g., Craik & Byrd, 1982). For decades, there has been ample experimental evidence that there is a less efficient short term memory system with age (e.g., Craik, 1968). This is supported in the real world by a large number of older adults' complaints of memory problems.

Since working memory, by definition, includes both a storage component and a simultaneous processing component, this concept has been an attractive choice as a causal factor in explaining age-related cognitive performance decline. Although the term *working memory* has not been in active use that long, Welford (1958, as cited in Salthouse, 1991b) was perhaps the first researcher to note that it was just this problem of simultaneously storing information and performing processing operations that was a particular problem for the elderly.

Working memory limitations have been found to be particularly compelling in examining cognitive aging. Recent research has begun to converge on evidence for a decrease in the capacity of working memory in the elderly (e.g. Craik & Simon, 1980; Wingfield, Stine, Lahar, & Aberdeen, 1988). In fact, specific deficits in WM for older persons have been documented often enough for this to become a favored explanation among cognitive aging researchers (e.g.

Hasher & Zacks, 1988; Kemper, 1988; Light & Anderson, 1985; Light & Capps, 1986; Rabinowitz, Craik & Ackerman, 1982; Stine & Wingfield, 1987; Wright, 1981). It has been suggested that this reduction in the capacity of working memory may serve to explain many of the deficits that accompany normal aging (Craik & Simon, 1980; Gick, Craik & Morris, 1988; Morris, Gick & Craik, 1988; Stine & Wingfield, 1987, 1988a).

Furthermore, this use of the concept of WM has increased as an explanatory concept (Hasher & Zacks, 1988) especially since the introduction of working memory measures such as Daneman and Carpenter's reading span test. This chapter will outline the importance of the relationship between working memory and cognitive aging. First I will look at some evidence that suggests that older adults have reduced processing resources available for cognitive performance. Then, studies that directly examine the notion that there is a limited WM capacity with age will be discussed. Finally, I will explore the importance of such a possibility in the explanation of cognitive deficits associated with increasing age.

A Reduction of Processing Resources in Aging?

There are task dependent effects of aging. For example, when attention is divided between two tasks, or reorganization of the stimuli is required, the elderly show decreased performance in relation to young adults (Craik, 1977). It is findings such as these that suggest there are cognitive deficits associated with aging and that cognitive capacity declines across the lifespan.

Dual task performance, in general, assumes that optimal performance is a function of the amount of resources available, how they are allocated (efficiency), and the difficulty of the task or tasks at hand (demand for the resources). This assumes a finite processing capacity (e.g., Kahneman, 1973) , and the system will supply the resources necessary for optimal performance as long as they are available. For excellent general reviews and discussions of attention and dual task performance the reader is referred to Wickens (1987) and Navon and Gopher (1979).

Limited capacity models of attention have certain assumptions: (1) cognitive function is constrained by the resources momentarily available. (2) the multiple components occurring on all tasks vary in the resources necessary for maximal performance. That is, there are very demanding tasks, and there are very easy or even automatically accomplished tasks. The processing resources hypothesis can be consider the mother of the working memory hypothesis. Therefore, the possibility of a reduced WM system in aging is a sub-theory within the perspective of reduced processing resources in age.

It has been put, that "there is good evidence that aging and divided attention have similar effects on memory" (Craik & Byrd, 1982, p.198). It is the more effortful conscious processes that are shown to decline with age, and the more automatic processes that remain relatively stable (Hasher & Zacks, 1979; Howard, Lasaga & McAndrews, 1980). One idea is that older people are able to carry out effective processing, but do not do so spontaneously - that is, they have a production deficiency (Craik & Byrd, 1982).

Compared with younger adults, older adults are disproportionally affected by dual task activities when both the primary and secondary tasks involve verbal materials (letters) than when the primary-secondary task pairings represent different processing domains (Vaida & Hoyer, 1989). That is, there are age differences implicated in the domain specificity of dual task interference - at least in the verbal domain. This suggests that older adults are deficient in sharing domain specific processing resources. It is also possible that the older adult is deficient somehow in either the amount or the efficiency of some general purpose resources. If so, then any secondary task should produce an age effect, that is differential performance, regardless of the similarity of the primary and secondary task domains.

It is well established that dividing a subject's attention during a task often results in a decrement of performance on that task. For example, during presentation of a word list, dividing attention of the subject results in decrement in free recall of the words (Craik & Byrd, 1982). A possible explanation for reduced performance under divided attention conditions is that there is a reduced amount of attentional resources necessary to carry out elaborative and deep (semantic) processing (Craik & Byrd, 1982). That is, there is less formation of new connections between items due to a lack of attentional resources.

Many cognitive aging researchers assume that older adults are at a particular disadvantage when under divided attention conditions (Inglis & Caird, 1963 and Kirchner, 1958 as cited in Craik & Byrd, 1982; Lorsbach & Simpson, 1988). Take for example, Lorsbach and Simpson's (1988) study which used a probe reaction time dual task procedure to examine capacity demands for a letter matching task. They found that the letter matching was demanding for all subjects, but even more demanding for the older adults, and this difference was greater in a categorical matching task as opposed to a physical matching task. They concluded that elderly adults have particularly pronounced performance decrease when categorical information is required. The conclusion that a decrement in attentional capacity for older adults, particularly in relation to the retrieval and comparison of deeper categorical information is intriguing. I will argue in Chapter 7 that this might not always be the case.

Besides the finding that the elderly are particularly deficient at performing tasks when they are in a divided attention situation, there are many other cognitive declines associated with age. Furthermore, there are a good number of theories that are said to account for these age differences in cognitive performance.

There is now in the literature a long list of performance decrements that are said to occur with age. A sample of some findings include (1) The elderly show particularly poor performance on tasks that involve free recall. Performance declines are not as pronounced in a cued recall or recognition situation (e.g. Craik, 1977; Schonfield & Robertson, 1966). (2) Older adults have difficulty on intentional memory and categorical clustering in free-recall (Howard, McAndrews & Lasaga, 1981). (3) The elderly show poorer incidental recognition and recall of words presented in lexical decision tasks (Howard, 1983; Howard, Shaw & Hersey, 1986). (4) Elderly show *slowing* in a wide range of cognitive process (e.g. Birren, Woods & Williams, 1980; Salthouse, 1982).

There are actually varying themes on the cognitive resources hypothesis in aging. Speed can be considered a resource available to us as we perform cognitive tasks. It is possible that there is a general loss of conceptual speed with age that accounts for the variety of performance decrements (Birren, Woods & Williams, 1980; Salthouse 1982, 1991b; Waugh and Baar, 1982). The *cognitive slowing hypothesis* predicts that age differences should be eliminated in slow or self-paced tasks and conditions, or on the other hand, exacerbated by very fast presentations rates. It has been shown that fast rates of stimulus presentation can lead to age-related performance decline (e.g., Wingfield, Poon, Lombardi & Lowe, 1985; Stine & Wingfield, 1987). Cohen (1979) provides support for a slowing with age when she found that elderly adults had problems integrating information when it was presented rapidly.

Craik and Rabinowitz (1985) found no support for the slowing hypothesis when they attempted to reduce the poor performance of the older group by slowing down presentation rates. It was only the young adults who benefited from the slower rate; the elderly group did not benefit at all. Rehearsal rates have been suggested as the most sensitive to any time parameter, and Salthouse has measured rehearsal speed in older adults and has reported age-related slowing (Salthouse, 1982).

Another appealing theory to explain cognitive decline with age is best exemplified by the phrase "Use it or lose it". The *disuse hypothesis* of aging is particularly appealing because of its standing in the everyday culture, as it describes memory as a sort of muscle. That is, under this hypothesis, if one does not continue to use one's cognitive resources and stay active, then they will deteriorate. On the other hand, if one stays healthy and active, and is supplied plenty of intellectual stimulation, then no (or at least less) mental degradation should occur.

Immediate Memory Limitations with Age?

Despite all the immediate memory differences that occur with age, we know that young and elderly adults typically perform equally well at the task of remembering a list of random digits. It is only when "loaded" or burdened with additional processing demands that the elderly performance begins to drop off (Craik, 1977). That is, despite all the age-related performance decrements that have been discussed, there are some cognitive measures which stay relatively stable. These 'primary memory' tasks such as digit span and the recency effect in free recall show slight age decrements, if any at all. The necessary information is still perceptually present or activated, hence there is no need for reorganization. In other words, these simple tasks do not require a great deal of involvement, if any, of working memory.

Although there are mixed reports as to whether simple letter spans and word spans (i.e., memory for simple lists of letters or lists of words) do tend to decrease with age (Burke & Light, 1981; Light & Anderson, 1985 vs. Craik, Morris & Gick, in press; Wingfield, Stine, Lahar & Aberdeen, 1988), it appears that an increase in the pool of choices (choices that could be on the list to be recalled) leads to smaller amounts accurately recalled by the older adult (Craik, 1968). Regardless, span measures intended specifically to tap working memory show even larger performance differences between young and old. The fact that older adults demonstrate distinctive differences in performance under heavily "loaded" conditions suggests a difference in working memory capacity with age. This finding occurs with working memory tests designed to place a burden on the subjects' working memory system in order to measure not only storage but manipulation of information as well (Daneman & Carpenter, 1980, Daneman & Green, 1986; Wingfield et al., 1988).

The finding that older adults are equivalent in performance to young adults on tasks that are relatively simple (such as lists that draw from a limited pool of choices such as random digit lists) is supported by a report from Wingfield, Stine, Lahar and Aberdeen (1988). They report a specific age deficit in WM capacity as measured by three tests of listening ability that increased the role of WM. The sample of young and elderly adults they tested performed virtually identically on a forward digit span test. When these same subjects were given lists of words to recall, the young subjects did recall more than the older adults, and this advantage for the young subjects was magnified when a third test was administered that required a simultaneous processing of the materials.

Further evidence of specific WM limitations in adulthood arise from the predictions of cognitive task performance by tests of working memory or by seeing differential performance on tasks that tax the working memory system. These methods have also met with mixed results. For example, Susan Kemper has found that measures of working memory correlate with running memory span (Norman, Kemper, Kynette, Cheung, & Anagnopoulos, in press). Light and Anderson (1985) failed to find a relationship between WM spans and memory for paragraphs.

In summary, age differences are observed when heavy demands are placed on storage or the speed of operation, suggesting WM differences in old adults as responsible for poor performance on various cognitive tasks (see Cohen, 1979). If older adults have limited WM spans, we can then examine the effects of aging, hence a decrease in WM, on various cognitive tasks. As we explore the WM hypothesis with age, there is much empirical work that has yet to be done. Salthouse (1990) recently has pointed out some specific areas in the field of WM and aging that need to be filled. For example, most every study has relied on a single measure of WM rather than a battery of tests which may be more reliable assessors of WM.

WM certainly plays an important role in many aspects of cognitive activity - for example, we could not produce or comprehend speech at the discourse level without a working memory system. In fact, the role of working memory is of particular interest because of it's great importance to the human information processing system. Indeed, *working memory* is now considered by many to be the primary hypothesis to explain age-related decrements in cognitive performance. The next chapter will explore the implications of a reduced WM system with age on the production of language.

CHAPTER 4
Language, Working Memory and Aging

Generally, an older adult's language production appears equally competent to that of a young adult. However, the production of speech requires at least semantic decisions, phonological encoding and articulatory skills. If any (some, or all) of the steps involved with speech production are dependent on a limited pool of cognitive resources, a clear prediction would be that elderly adults would show some speech production deficits. It is important to consider briefly what happens in language production. That is, are we sure that WM is even involved ? If so, what might be the implication of a decreased WM capacity with age on the production of fluent speech?

Language Production

Conscious planning decisions involved in speaking must place demands on working memory. In fact, there is clear evidence that semantic processing makes demands on speakers, at least when they are planning single sentences (Goldman-Eisler, 1968; Power, 1981). Goldman-Eisler found this to be true as she had subjects describe a series of cartoon pictures. Power (1985) and Rosenberg (1977) report that young subjects take longer to generate sentences from a pair of unrelated words than a pair of related words. Working memory must be involved in speech planning at some level.

Speaking requires energy as the semantic processes necessary in speech production make demands on the speaker, and specifically on WM. Conscious planning decisions make use of WM. The extreme case would be if all of WM was necessary for a sentence or discourse to be produced. But speakers can talk and plan at the same time. Moreover, experiments show that subjects can perform two tasks at once, yet performance may suffer. Whenever two tasks are performed concurrently, there may appear a speed and accuracy tradeoff, especially as the tasks become more demanding. The extent to which speech calls upon the use of stored knowledge can be expected to vary in different situations. For example, semantic processing will be much easier if the information is readily available than if it is not. Fewer demands would then be made on WM.

What are the steps necessary to produce speech? Speaking is an intentional activity. By definition it is under conscious control, and therefore we must invest some attention into matters of planning what to say. When we speak, we start out with a thought, concoct some group of words to convey that thought, and program our motor activities to speak that thought.

Speech must begin with a conceptualization phase, where we plan and generate a message. This conceptualization phase has been specifically labeled as the point at which we would assemble ideas into propositions (Bock & Irwin, 1980). It is only after we have determined the intended message that we formulate the method in which to convey that message.

The second phase of speech planning is a formulation phase. Here we generate a surface structure, and execute a phonological encoding. This would include the syntactic realization of the spoken message. Any model of language production must include a syntactic stage. There are linear and precedence relations that must be established among words, or in other words, syntactic choices must be made. Speakers of French, for example, must plan utterances with adjectives placed after the nouns that they modify, whereas speakers of English must position adjectives before the nouns. Research on the production of syntactic relations has taken a variety of forms (e.g. Bock, 1986) and researchers are in agreement that the 'structure' or 'syntactic' component of the speech production system is a specialized and encapsulated system; that is, one separate from the semantic system (Bock, 1987; Chomsky, 1965; Garrett, 1984).

Execution of the phonetic plan by a speaker results in the product of speech (Levelt, 1989). The final stage is then an articulatory phase where we execute a motor plan. Levelt (1989) summarizes the entire speaking process as one consisting of conceptualization, formulation, (where grammatical, phonological and articulatory encoding occur), and articulation. In brief, the first task of the cognitive system is to generate a message, and then the system must convert that message into a spoken message. To accomplish that task, the system uses the lexicon, and the syntactic and phonological rules of the language.

Garnham (1985) has specified three methods of studying speech production. One method would be to attend to a breakdown of the system. For example, research on aphasia or the analysis of speech errors would address the breakdown of the language production system. A second method for studying speech production is to use controlled production experiments where subjects are given a stimulus, and asked to produce a sentence, a word, or a stretch of speech. The rationale in this case is that normally the message is selected by the speaker, but in controlled production experiments, the message is provided. These experiments therefore address the question of how difficult it is to put the message into words. The most common measure in these studies is the time taken to begin speaking, reflecting the difficulty of formulating a response. A third method of studying speech production is to model production using computer simulation (e.g. Dell , 1986).

Most research in speech production has developed models based on a breakdown of the language production process. This breakdown can manifest itself in terms of slips of the tongue, speech errors, and the aphasias. Indeed, the current models of speech production have relied heavily on slips of the tongue (Motley & Baars, 1976; Motley, 1985), hesitations and pauses, and speech errors (Dell, 1986; Stemberger, 1985). Fluent speech production is a far less studied area than speech comprehension (Klatzky, 1988; Garnham, 1985), mainly because of the difficulty in controlling the output process.

Speech Production and Aging

The ability of the older adult to comprehend spoken language has been a central research area in the field of cognitive aging. Some reviews are available (e.g., Light & Burke, 1988; Spilich, 1985). Much research has addressed all levels of speech comprehension, from access to the lexicon, to recall of spoken narrative prose. As indicated, the ability of the older adult to produce speech has been a less studied topic than comprehension (Klatzky, 1988). Once again, this is mainly because of the difficulty of maintaining experimental control over speech production. Much of the speech production and aging literature considers acoustical characteristics of the speech (e.g Liss, Weismer & Rosenbek, 1990; Oyer & Deal, 1985; Smith, Wosowicz & Preston, 1987). However there have been a handful of studies that attempt to address language skills in aging adults, some of which have concluded that linguistic skills deteriorate with age (e.g., Albert, 1981; Kemper, 1988)

The hypothesis that the old have a decrease in processing resources predicts that there would be an increase in planning time and an increase in speech errors as they speak. As in comprehension, there are certain variables that will put a load on the memory system of the individual as they produce speech: variables such as the number of propositions combined in a single sentence (Kintsch, 1974), the distance between references to a common concept (Daneman & Carpenter, 1980), and the separation of components of a proposition within a sentence

(Kemper, 1988). That is, if one were to produce an utterance in which one proposition is embedded within another, as often happens, it is necessary to hold in memory the first component of that first proposition while producing the second proposition. This is an impressive ability if we assume that linguistic performance is constrained by memory function (Hasher and Zacks, 1988).

The effects of age on written output suggests that some parts of the language production capacity decline, while others stay relatively intact (Bromley, 1991; Kemper, 1987, 1988; Kynette & Kemper, 1986). Bromley (1991), in a written production study, found that vocabulary diversity increased with age. The finding of increased variety in vocabulary is consistent with Obler's (1980) report of a more elaborate written output by old adults in comparison to young. However, these were not speeded tasks. Bromley allowed the subjects to write for as long as they like. For this reason, the finding of increased vocabulary diversity may have limited applicability to fluent or spontaneous speech production.

Vocabulary use has been examined in studies of spoken discourse. Walker, Roberts & Hedrick (1988) elicited spoken discourse from younger and older women. They examined factors such as the length of the utterance, the diversity of vocabulary use, and the number of speech interruptions. They report that length of utterance declined with age, but vocabulary diversity increased. This important property of speech production, vocabulary, seems to be stable across age (Light, 1988; Salthouse, 1991b). Furthermore, it is possible that an increased vocabulary of the elderly adult may be paralleled with an increased ability to use this vocabulary.

There are also reports regarding the length and complexity of utterances in spoken discourse. Walker, Hardiman, Hedrick & Holbrook (1981) found shorter productions from older adults. Kynette and Kemper (1986), in a study of spontaneous speech, found no change in length of utterances but they did find a decrease in the syntactic complexity of these utterances.

Kemper (e.g., 1988) has also reported that the ability to imitate and produce syntactically complex sentences decreases with age. Kemper interprets these findings in terms of the elderly subjects attempting to avoid taxing the WM system. If older adults have smaller working memories, this would be very adaptive. Ulatowska, Hayashi, Cannito, and Fleming (1986), however, have found no age-related change in the use of complex references. Ulatowska et al (1985) also report from an examination of discourse in middle age and old adults, that there was no difference in the amount of language produced; but there was a decrease in the amount of information conveyed. This finding would also prove to be an adaptive style of handling a decrease in working memory or conceptual speed with age.

Conclusions

It appears that the ability to acquire new information may be diminished with age, but not the ability to use old information. In fact, it is possible that the length of life may increase one's strategic array in order for the older adult to generate language in an even more elaborate manner than the young adult. This would leave them as better story tellers, and valuable resources in our society.

However, performance is limited by factors such as memory and attentional limitations Although there is plenty of evidence that these limitations affect the elderly adults' abilities in speech comprehension, there is still a need to investigate the possible role of cognitive limitations in the production of speech. The question remains : Would a life-time of speaking experience allow the elderly to overcome what might otherwise be a drop in speech production performance associated with age ?

WM is hypothesized to be involved in so much of our cognitive activity. It holds as a powerful explanatory factor in today's literature. That is, a decrease in the capacity of working memory with age is postulated as an antecedent to the cognitive decrements associated with age. Furthermore, WM is presumed necessary for language production and comprehension. The next chapter will present a study designed to address some of the issues that have thus far been discussed.

CHAPTER 5
Experiment

Introduction To Experiment

In the experiment presented here, the role of working memory (WM) in speech production will be compared across young and old adults. Current theories of cognitive aging suggest a possible role of the capacity of working memory serving as explanation for deficits seen in discourse processing of the elderly (e.g. Gick, Craik & Morris, 1988; Morris, Gick & Craik, 1988; Norman, Kemper, Kynette, Cheung & Anagnopoulos, in press; Rabinowitz, Craik & Ackerman, 1982; Stine & Wingfield, 1987). This study, in contrast to earlier work which has focused on the role of working memory in language comprehension and perception, will examine the possible role of working memory in speech production processes by looking at an active performance measure of language generation. Tun (1991) has recently suggested, in fact, that older adults find it more difficult to simultaneously hold a conversation while performing a complex cognitive task than do young adults.

If older adults demonstrate distinctive differences in performance under heavily "loaded" conditions, then this would suggest a difference in working memory capacity with age. It has been demonstrated that a secondary task of remembering digit lists shows a significant slowing of reasoning time in young adults (Baddeley & Hitch, 1974; Hitch, 1980; Hitch, 1984; Power, 1985). If there is an age related decline in the capacity of working memory, then we should expect to find strong correlations between measures of working memory span and performance on a loaded divided attention task.

In the process of speech production, speech starts as a message or an idea which then gets converted into its output form. As previously indicated, models of speech production tend to assume at least two stages, a process of conceptualization, and one of assembly. That is, first the underlying ideas must be organized into expressible propositions and then these propositions must be assembled into a surface syntactic structure (Bock & Irwin, 1980; Fodor, Bever & Garrett, 1974; Kintsch & van Dijk, 1978). This study will allow for a comparison across age of the conceptualization and assembly processes of sentence production. The use of Kintsch's text base proposition system allows for both a qualitative and a quantitative analyses (Bovair & Kieras, 1985; Kintsch, 1974; Kintsch & van Dijk, 1978; Turner & Greene, 1977). That is, we can measure the number of propositions, or 'idea units', in order to ascertain an amount of *information content* of each sentence generated.

If we are to study speaking in any way, we must model speech production in the lab. In generating speech, the speaker wants to convey some information or achieve some purpose by means of saying something. The speaker, then, will select some information for expression that is expected to achieve this goal. If we can provide this goal (e.g., this *thought*, this *information*) then we can have some control over the speech production process, and also be able to manipulate it. So in order to model sentence production, we can give subjects a *thought*, and have them make up a sentence. Furthermore we can use a technique that will allow for an examination in the fluctuations of processing demands inherent in speech production.

A useful technique for studying sentence production and working memory was used by Power (1985). This is the method that will be used in this study. Power had young subjects produce sentences using experimenter provided pairs of nouns which were either related or unrelated. Subjects also had a simultaneous memory pre-load of digit lists while making up some of the sentences.

In fact, one of the first tasks used to examine the role of working memory was that of "loading" a person with an irrelevant task of remembering digit-lists while simultaneously performing another task (Baddeley & Hitch, 1974; Hitch, 1984). The logic of this argument is that if digits occupy a common working memory, they should interfere with the task at hand, and this should be especially evident when the digit strings are near the capacity of the working memory span. It has been demonstrated that a secondary task of remembering digit lists shows a significant slowing of reasoning time in young adults (Baddeley & Hitch, 1974; Hitch, 1980; Hitch, 1984; Power, 1985). Using this paradigm will be particularly useful in order to examine the question of reduced capacity in aging. If there is an age related decline in the capacity of working memory, then we should expect to find even greater changes in performance under a simultaneous memory load. Additionally, I will look for strong correlations between measures of working memory span and performance on a loaded divided attention task.

This study, in contrast to earlier work which has focused on the role of working memory in language reception, will examine the possible role of working memory in speech production processes by looking at an active performance measure of language generation. A main measure of interest is the latency to production of the sentences. The latency is the time from the moment that the noun pairs are presented, to the moment when the subject initiates the sentence in response. This time is assumed to be the time needed to concoct the sentence, or to connect the noun pairs; that is, latency is a measure of planning time. It is a reaction time measure. According to Levelt (1989), this would represent the time of getting the preverbal message together, the product of conceptualizing and selecting relevant information to be expressed.

The use of a voice latency technique is especially good for use in aging research. Both Nebes (1978) and Hartley (1988) have reported no age difference in the baseline voice latency of young and old adults. A similar sentence generation task as will be used in my study has been used by Nebes and Andrews-Kulis (1976) with old adults. They found that old adults could generate a sentence as fast as a young adult. Salthouse and Somberg (1982) showed that there was a dual task decrement of voice reaction time when paired with a visual discrimination task for the old as opposed to the young. Their subjects, however, did not need to formulate a message, since the responses were simply "yes" or "no".

One aspect of varying task demands was the simultaneous memory load, and a second method invoked by Power (1985) was to vary the word pairs from which subjects were to make up the sentences. He presented both related word pairs taken from association norms, and unrelated pairs of words. As was expected, when Power presented young subjects with a related pair of words (such as uncle-aunt), they were much faster to producing a sentence than they were for unrelated pairs (such as bottle-pillow). Power also expected that subjects would be slower to produce a sentence as they have more digits to remember. This, however, was not the case. Although the intuitive finding is that as we increase memory load, subjects will be slower on the secondary task of sentence generation; yet, as subjects had more digits to remember, they actually sped up. It seems that subjects were opting for a strategy. That is, they were trying to get the sentence generation portion of the task over with as quickly as possible, in order to return to the recall portion of the task before the memory trace decays.

This strategic finding of speedier sentence production under a memory load will be interesting to explore in an elderly sample. The literature suggests that older adults do not engage spontaneously in strategic memory maneuvers as much as young adults. Along with the assumption that the older adult has reduced capacity of WM or smaller amount of resources available for task performance, I clearly expect a differential decrease in speech production measures with age.

This strategy on the part of Power's subjects was also evident in other measures of sentence production performance. Power measured word length, time of the sentences (duration), and information content. On average, all of these variables were reduced under load.

The processing resources approach is particularly appropriate for this research. There is considerable evidence that the aging adult performs less well than the young on tasks that require simultaneous storage and processing (see Wright, 1981, Craik, 1977; Chapters 3 and 4 of this thesis). In fact, there are specific predictions about the reduced attentional resources of the elderly adult leading to increased planning time in speech, increased speech errors and similar changes in language production. However, none of these predictions have yet undergone empirical investigation (Light, 1988).

There is also a measure of word recall that will be collected in this study. After collection of the speech production data, an incidental free recall test will be administered for the words presented during the main task. That is, the subjects will be asked to recall as many of the noun pairs as they possibly can from which they generated the sentences. Schonfield and Robertson (1966) reported that older adults do not show poorer performance on tests of recognition memory, but do have poorer performance than young on tests of free recall. It is expected that the older adults will recall less of the words presented than the young adults. It is also expected that the older adults will recall differentially less of these words that appeared under the memory loaded conditions.

Finally, a battery of eight memory span measures will be administered to all subjects. There are two main reasons for collecting a number of measures of memory span. First, there are no adequate data regarding the predictive quality of tests of working memory. As indicated, many researchers use a forward and backward digit span to assess, respectively, simple storage capacity and working memory capacity. These tests rarely predict cognitive performance. However, the reading span test (Daneman & Carpenter, 1980) has been found to predict reading abilities. A speaking span test (Daneman & Greene, 1986) has been claimed to be predictive of the processing and storage functions of working memory during sentence production. Since this study requires subjects to produce sentences under varying amounts of cognitive load, it is expected that the speaking span test will be the highest predictor of performance.

The second reason for administering eight different memory tests is to analyze these tests for relations among themselves. Those who test working memory tend to use one or two tests of working memory capacity, and there is a lack of data regarding the relationships between the different tests available.

To summarize, this study will examine elderly and young participants' performance on a dual-task experiment. The two tasks involved are memory for random digit lists and production of sentences from noun pairs. Each of the tasks will also be performed as a single task by the subjects in order to gather baseline performance measures for comparison. More traditional measures of working memory span (c.f., Daneman & Carpenter, 1980; Hartley, 1986 ; Light & Anderson, 1985) will be collected on all subjects to determine if performance can be predicted from working memory span for either young or old adults.

A third sample will be introduced in this study for a number of reasons. Since memory is so different for old and young adults, one possible contribution to the increase in performance on the part of the younger adult is that they are in school where memorizing is a common activity (Ratner, Schell, Crimmins, Mittelman & Baldinelli, 1987). That is, it is possible that comparing elderly subjects with a sample of rather homogeneous college students tends to inflate differences in performance between young and old. One of my goals in this experiment will be to compare the performance of both young and old adults on the span tests with another young sample that is not drawn from school. Indeed it would be nice to have both an "in school old" sample and "out of school old" sample to complete the design, but elderly adults taking classes are a hard sample to procure.

The other reason why a group of young adults who are not currently enrolled in school will be useful is that speech production can be highly variable, and this has been reported to be especially so in the old (Albert, 1981). The college student control group that is conventionally employed in cross-sectional aging research is a very homogeneous sample. Often it is reported that the older samples are more variable in both the measures we derive in our testing procedures, and in the backgrounds from which they come. It is possible that the older subjects, if they indeed do produce more variable speech, do this because of the variety in their day to day experience. For this reason, it may be more appropriate to compare their performance in speech production tasks to a group that is drawn from the same heterogeneous community. Finally, selection of this third group of non-student young adults in this study will allow for an examination of differences in the variability of dependent measures that often results in aging research. These issues be addressed in detail in Chapter 7.

Specific aims of this study

1) This study aims to investigate the effect of increasing memory demands on speech production across in three groups of subjects. These subject groups are selected to be most likely to have differing 'baseline' memory or resource capacities.

2) This study will examine the natural characteristics of sentence production under a variety of conditions while recognizing the need for experimental control over the manipulations. My goal will be to use a task more like a natural everyday task of production and memory performance than the typical laboratory test.

3) By using a large set of memory measures, this study can thoroughly examine

   a. possible WM decreases with age in an array of domains

   b. possible relationships among these different memory measures.

c. the predictive quality of eight different tests of memory on the speech production measures collected in the main study.

4) This research will collect scores on a speaking span test which is postulated as predictive of sentence production. It is expected to be a more predictive working memory test than the tests in domains of listening and reading for sentence production. This may be especially so in the conditions where sentence generation occurs with a simultaneous memory load.

METHODS

SUBJECTS

Eighteen Brandeis University undergraduates with ages ranging from 18 to 22 (mean age=19.17, SD=1.20), 18 community dwelling elderly volunteers ranging in age from 60 to 80 years old (mean age=69.78, SD=4.83) and 18 community dwelling young adults ranging in age from 24 to 29 years (mean age= 26.61, SD= 1.42) participated in this experiment. All subjects were native speakers of American English, and were screened for good vision, hearing, and health. The university students received class credit for Introductory Psychology class in return for participation. The other two groups of subjects were elicited from advertisements in the greater Boston community and were paid a small honorarium ($5 or $10) for participation. The community volunteers represented a wide variety of occupations and educational levels.

One criterion for participation for the young-non-student (YNS) sample was that they had not been a formal student for at least the previous two years prior to the test session. Furthermore, no subjects in the old sample reported current participation in formal education activity. Although none of these subjects were currently students, they had on average, participated in more years of formal education than the young-students (YS). The young college student sample (mean= 13.17, SD=1.20) differed in mean level of formal years of education from both the old (mean=15.00, SD=1.72), $t(34)=3.72$, $p<.001$, and from the young non-student group (mean=15.28, SD=1.07), $t(34)=5.56$, $p<.001$. There was no significant difference in the level of education for the old and the non-student young groups, $t(34)=0.58$, N.S.

There were no significant differences in vocabulary levels for any of the groups, as measured by the vocabulary subportion of the Wechsler Adult Intelligence Scale (WAIS; Wechsler, 1955). The means for vocabulary for the old, young-students (YS), and young-non-students (YNS) were 67.44 (SD=8.61), 63.00 (SD=6.25) and 63.33 (SD=7.73) respectively. Full descriptive statistics of the background measures of age, vocabulary and education are presented in Appendix A.

Finally, the sampling method did not control for gender equality, and that is reflected in the gender distributions of the samples used, all of which had more females than males: The Old sample had 12 females and 7 males, YNS included 11 males and 7 females; and there were 15 females and 3 males in the YS group. An older group that includes more females is most representative of the older population as a whole, although this distribution may not be representative of the two younger samples.

DESIGN

The general design of this study was a 3(age/subject Group: Old, YS & YNS) X 2(Relatedness: Unrelated and Related) X 3(Memory load: None, Low-3 digits, and High-6 digits) mixed factorial design. The factor of Group (Young-Student vs. Old vs. Young-Non-Student) was the only between groups variable. The other two factors were within subjects variables. The factor of Relatedness of the noun pairs had two levels: related and unrelated. The digit Memory load factor had three levels of 0, 3 or 6 random digits. This Memory load was presented in blocks such that every subject received all trials of a particular digit-length successively with the order of these blocks counterbalanced to control for possible order effects. The noun pairs were randomly presented with the restrictions that an equal number of related and unrelated pairs fall within each digit level and in each block-order an equal number of times.

STIMULI

24 noun pairs were constructed from which the subjects were to make up sentences. 12 of the noun pairs were highly associated pairs such as INDIAN - ARROW, TABLE - DOOR, and UNCLE - AUNT. The other 12 noun pairs were unassociated pairs such as BABY - DUST, RABBIT-DOLLAR, and DOG - OWL. Half of the noun pairs were taken from examples presented by Power (1985) and half were taken from the unrelated and related associational input sets presented by Rosenberg (1977). All words were equated for frequency and length, and all were short, high in frequency, highly imageable, and highly concrete nouns. The complete list of stimulus word pairs is presented in Appendix B .

APPARATUS

The noun pairs were presented on a *Macintosh Plus* computer by a program written in *Turbo Pascal.* Random numbers of 3 or 6 digit length were generated from random numbers tables and also presented by the same computer program. The 3 digit numbers were presented for a duration of three seconds and the six digit numbers were presented for six seconds. There was a 1.5 second blank screen time between presentation of the digit-lists and presentation of the noun pairs. The computer program presented a beep sound at the same time as the presentation of the noun pairs, and this beep sound was fed into the left channel of a *JVC TD-W503* dual cassette tape recorder which was simultaneously recording the subjects' verbal responses on the right channel. This allowed for the complete transcription of subjects' latency to production of each sentence with the use of *Soundcap*, a program for the *Macintosh* which allows digitized sound to be measured to the nearest millisecond. In other words, the tapes were fed back into the computer for transcription and measurement with the use of *Soundcap.*

Subjects all received a hearing screening evaluation, which was accomplished by doing an audiogram analysis on a *MAICO MA 39* audiometer.

PROCEDURE

Subjects read instructions which told them they would be asked to do two things at once (see Appendix C for a copy of the instructions for this task). They read that their primary task was to remember numbers that were either three or six digits in length. While they were remembering the numbers they would also have to make up a sentence from a pair of words which would appear on the computer screen a short time after the numbers disappeared. In other words, their task was to say out loud the numbers that appeared on the screen, make up a sentence as soon as the words appeared and then say the numbers again. They also read that sometimes they would not have to remember any numbers while making up the sentence. The subject was told by the experimenter that they would always know how many digits they would be required to remember before they begin any given trial. The computer prompted both the subject and the experimenter when a change in digit-load occurred. Each subject was given a total of nine practice trials, three with each type of digit-load. When the subjects were ready the experimenter pressed a button which would begin a trial.

A surprise free recall test for the noun pairs presented was administered after all 24 trials. Subjects were asked to write down as many of the words that appeared during the test as they could remember. Subjects were given as much time as they liked for this task.

The subjects all participated in a simple digit task where they read digit lists of 3 or 6 digits in length from the computer screen and after varying amounts of time were asked to verbally recall the strings (the time was meant to correspond to the time a subject would take to make up a sentence, so the times randomly varied from 2 to 8 seconds). This simple digit task served to determine if subjects could remember digit strings without an additional task. Results show that all subjects have perfect digit recall for 3 and 6 digit strings when no additional intervening task is present; therefore this task will not be analyzed or discussed further.

Subjects also were tested on the following three subtests of the Wechsler Adult Intelligence Scale (*WAIS:* Wechsler, 1955) : forward digit span, backward digit span and vocabulary. Administration of six memory span tests and subject debriefing completed the experimental session. The entire session took about one and one half hours to complete.

The six memory span tests were designed to tap a variety of domains and different levels of primary and working memory involvement. Five of these six tests were based on tests designed by Meredyth Daneman and her colleagues (Daneman and Carpenter,1980; Daneman and Green,1986). These tests will be detailed in the next section.

MEMORY SPAN MEASURES

Simple Auditory Span

In the listening word span test a subject hears progressively longer lists of unrelated words and simply recalls them back. It is a relatively 'simple' test, designed as an ordinary simple span measure for words. The words selected were all high frequency unrelated words. The words were presented verbally by the experimenter at a rate of approximately one per second, and lists ranged from a length of two to a length of nine words. The score for this test is taken as the length of the longest list a subject can accurately recall after auditory presentation.

Loaded Auditory Span

In the loaded auditory span test, a subject heard progressively longer lists of sentences for which they were to state whether each sentence was true or false and then recall the last word of each sentence. The stimuli consisted of a set of 60 true-false statements ranging in length from 10 -16 words. After each sentence, the subject had to make a true or false judgement, and after a set of sentences, the subject had to recall the last word from each of those sentences. The 60 sentences were grouped into sets of 2,3,4,5, or 6 sentences, with three groups for each set size. When the subject had heard all sentences within a particular set, the subject then heard a tone, which signalled them to recall the last words of each of those sentences. For a set size of two, a subject would hear *Twenty-two is the number of words in the English alphabet* and would respond *False*. Then they would hear the second sentence: *The mythical unicorn looks like a horse with a horn on it's head*, and would respond *True*. At the end of the second sentence they would be required to recall the words *ALPHABET* and *HEAD*..

Subjects continued to hear progressively longer set lists until the subject failed all the sets at a particular length. At that time, the test was stopped. This test was preceded by three practice sets at the two sentence length.

Subjects' spans were taken as the set-size level at which they were able to recall all of the final words for at least two out of three sentence sets at that size level. Credit was given for recalling all of the words, regardless of order. In addition, a half credit was added to the span measure if he or she recalled all of the words in just one of the three sets at the next higher level. (If a subject recalled all of the words for one out of the 3 sentence sets for the next two consecutive set-size levels in a row, full credit was given for the lower level of the two and an additional half credit was given for the higher level.)

Simple Reading Span

The simple reading span test is similar to the simple auditory span test, except the subject reads aloud progressively longer lists of unrelated words to be recalled. The words were all high frequency words. It is a simple account of how many words a person can read and consistently recall, so the span measure is the longest list of words a subject can successfully reproduce regardless of order.

Loaded Reading Span

In this test subjects read aloud progressively longer lists of sentences, and at the end of a set of sentences, they were required to recall the last word of each of those sentences. There was a total of 60 sentences ranging from 9-12 words in length. The sentences were grouped in 3 sets each of 2,3,4,5,and 6 sentences in in length. The sentences were in large bold type (one-half inch high) on individual index cards. This allowed the experimenter to control presentation of each sentence at a rate that was appropriate for the reading speed of each subject. There were three practice trials at the two sentence length for practice prior to the main test.

Scoring of this test was identical to that of the loaded auditory span test. That is, full credit was given for recall of all the final words for at least two out of three sentence sets at that size level and half credits were also possible.

Speaking Span

This test was patterned after the Speaking Span test introduced by Daneman and Green (1986). In this test, subjects silently read a set of words displayed one at a time on a computer screen. At the end of a set of words, the subjects were to generate aloud a sentence that contained each word from the set. For example, when presented with the set of words: CLOTHES, WHISTLE, OFFICER, the subject generated: I bought new CLOTHES. I WHISTLE to call the dog. I punched the OFFICER.

The test was constructed from 40 unrelated words that were all 7 letters in length. The words were arranged in two sets each of 2,3,4,5,and 6 words in length. All subjects attempted all sets in this test. Each set was preceded by a ready signal, and each word was presented at the center of a computer screen for 1.5 seconds, and at the end of a set, a blank screen and simultaneous auditory tone signalled the end of the set. At this time, the subject was required to generate aloud a set of sentences containing the words that just appeared on the computer. A separate sentence was required for each word in the set.. Subjects were instructed that each sentence must be grammatically correct for it to be counted as correct. Set sizes increased from sets of 2 to the final two sets of 6 words in length, until all 40 words had appeared. This allowed for two separate performance measures on this test to be calculated. The traditional method for measuring a working memory span from a test like this is to assign a score as the maximum set size that a subject could complete. This procedure provided one of two speaking span measures. A second score was obtained by examining the total performance, that is, the total number of words from which a subject successfully made up a grammatical sentence.

Alphabet Span

The alphabet span test was devised based on a task created by Craik (1986). In this test, subjects heard lists of unrelated concrete nouns and were asked to recall each list back in alphabetical order. There were 18 lists possible, 2 at each length of 2,3,4,5,6,7,8 and 9. Testing was aborted after a subject failed to correctly alphabetize and recall both lists at a particular list length. The score for this test was the length of the list that they could completely recall in the correct order, plus a percentage of the correctly ordered recall from the two lists at the next level. This percentage was the total number recalled in correct alphabetical order divided by the total number presented at that level.

RESULTS

Digit Recall

An analysis of subjects' ability to recall the random digits was scored with a strict criterion. Only those numbers recalled in the correct order were scored as correct. For the Young-Student (YS) subjects, when faced with three digits in the related words sentence generation condition, correctly recalled an average of 2.8, corresponding to 94.91% of these three digit lists (SD= 6.48), and an average of 2.8 (92.13%, SD= 11.60) in the unrelated condition. When faced with a digit-load of six digits they recalled 80.32% (SD= 14.63) of the digits in the related condition and 78.01% (SD= 15.25) in the unrelated condition, or an average of 4.8 and 4.7 respectively.

The Old subjects correctly recalled a mean of 2.8 numbers or 92.13% (SD= 11.95) of the three digit lists in the related condition, and 2.5 or 84.72% (SD= 19.65) in the unrelated condition. When faced with a digit-load of six digits they recalled averages of 3.9 in the related condition and 4.0 in the unrelated condition (64.12%, SD= 18.64 and 66.90%, SD= 19.72 respectively).

The average recall of the Young-Non-Student (YNS) group for the three digit lists was 2.7 (91.20%, SD= 16.29) for related and 2.8 (93.98%, SD=8.48) for the unrelated condition. Finally, in the six digit lists, they recalled a mean of 5.2 for related condition and 5.0 in the unrelated words condition. For the six digit lists, those average recall scores correspond to an average recall of 87.5% (SD=13.48) for related and 83.80% (SD=11.95) for the unrelated condition.

A 3(Group) X 2(Relatedness) X 2(Digit-length of three or six) ANOVA was performed on the percent digit recall measure. There was a significant effect of Digit-length $F(1,51) = 54.05, p < .0001$, where all groups recalled a higher percentage of the 3 digit lists than of the six digit lists. There was also a significant effect of Group, $F(2,51) = 8.24, p < .001$, and an interaction of Group X Digit Length, $F(2,51) = 5.30, p < .01$. This interaction appears to be due to the elderly group being particularly disadvantaged in the recall of the 6 digit lists, however, all groups are performing at ceiling in the three digit condition, so it would be inappropriate to interpret a finding of differential group performance on this task. There was no effect of Relatedness of the noun pairs on digit recall performance nor any other interactions among these factors.

Post hoc Newman Keuls' pairwise comparisons were computed to determine if all three groups differed significantly in the amount of digits correctly recalled. All comparisons were at the 95% level of confidence. No significant difference was found between the two younger groups tested, but the elderly sample did recall a significantly smaller amount of the digit lists than either of the two young subject groups.

It is important to note, that if subjects are faced with random digit strings of either 3 or 6 digit length with no intervening task, they rarely fail to recall the strings perfectly. All 54 subjects in this experiment were tested for recall of random three and six digit lists with no simultaneous task. They recalled these lists after a brief time period meant to correspond to the time of sentence production during the task. All subjects recalled 100% of both 3 and 6 digit strings when no intervening task was present. This result supports the conclusion that for both young and old adults, the intervening task of sentence production has a marked effect on digit-recall.

In summary, the digit recall data shows that all three subject groups are very good at successfully recalling short lists of numbers (three digits long) even while generating a sentence during storage. When the memory load is a bit higher (lists that are 6 numbers in length), the elderly recall a smaller percentage of the digits than their younger counterparts. It is certainly the case that all three groups are disadvantaged in recall of both short and long digit lists when faced with a concurrent task of sentence production.

Temporal Features of the Generated Sentences

Latency

The latencies were obtained by measuring the time in milliseconds from the presentation of the noun pair (±8 msec. computer error) to the time at which the subject began uttering the sentence. These latencies were obtained by digitizing each tape recorded experimental session which provided a visual display of the sound waves present during each trial.

Any latency that was longer than 15 seconds was considered to be out of the range of normal latencies for all groups. There were 3 cases that were considered outliers according to this criterion (0.23% of all cases; 1296 total latency measures) and each case was replaced with the subjects' mean for that condition.[2]

In terms of the range of the latencies, the most extreme values actually appear precisely under the conditions that we would expect.[3] The smallest latency was 0.844 seconds, produced by a YS subject under the heaviest memory load (6 digits) as they generated a sentence from a related noun pair. The largest latency (after removal of the outliers) was 9.830 seconds,

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[2] Two of the latency outliers were from a single YS subject generating sentences under a Memory pre-load of three numbers, one outlier in the related case and the other from an unrelated noun pair. The third outlying data point was from an Old subject, generating a sentence from an unrelated noun pair under a three digit load.

[3] Previous research (Power, 1985) has demonstrated that subjects are faster to produce sentences under memory load conditions, and also from related as opposed to unrelated noun pairs.

also by a YS subject, but in this case they were under no memory load, and were producing a sentence from an unrelated noun pair.

Every subject generated four sentences in each Relatedness X Memory load condition. The latencies to production of these sentences were averaged for each condition, resulting in six mean latencies per subject. These means for each condition are presented in Table 1.

Table 1. Mean latency to sentence generation under the different conditions for each group. Time is measured in seconds. Numbers in parentheses are standard deviations.

	UNRELATED			RELATED		
	0	3	6	0	3	6
Young-Students	2.67 (1.05)	2.06 (0.46)	2.12 (0.76)	2.04 (0.67)	1.79 (0.66)	1.80 (0.69)
Old	2.78 (0.62)	2.43 (0.75)	2.36 (0.63)	2.20 (0.48)	1.94 (0.55)	1.96 (0.53)
Young Non Students	2.70 (0.89)	2.23 (0.54)	2.03 (0.54)	2.53 (0.73)	2.03 (0.71)	1.84 (0.59)

A 3(Group) X 2(Relatedness) X 3(Memory-pre-load) ANOVA on latencies found a significant effect of Relatedness, $F(1,51) = 58.28$, $p<.0001$ supporting the observation that subjects are faster to generate sentences from related pairs of nouns. As expected, there was also a significant main effect of Memory load, $F(2,102) = 30.83$, $p<.0001$. That is, subjects are faster to generate sentences when faced with a concurrent task. Newman-Keuls' post hoc comparisons were computed (all comparisons are reported with a .05 significance level). These mean comparison's uncovered the fact that latencies are reduced when subject's have concurrent memory load, but there is no significant difference between a low memory load of 3 numbers, and a high memory load of six numbers.

There was no main effect of Group on latency. That is, overall, the elderly are no slower to start the sentences than the younger groups. However, this is not necessarily the case for all conditions because the Relatedness X Group interaction reached significance, $F(2,51) = 3.88$, $p<.05$. In order to examine more closely this interaction of Group X Relatedness, Newman Keuls' post hoc comparisons were computed (pairwise comparisons at the .05 level of significance), using the group means at each level of Relatedness. These group means are plotted in Figure 1.

The result from the pairwise comparisons found that the elderly subjects take significantly longer to generate a sentence from a unrelated pair than they do a related pair of nouns, as is the case for the young-students (YS). The YNS sample, however, show no significant effect of Relatedness of the noun pairs on latency. That is, there is no significant difference in latency when generating sentences from unrelated or related noun pairs for the non-student young sample. The slope, representing the increase in latency when generating a sentence from unrelated pairs (in comparison to related pairs) is large for the Old and YS samples, yet small and non-significant for the YNS group.

Another important aspect of Figure 1 is that in the unrelated condition, where subjects are generating sentences from a pair of unrelated nouns, the classic effect reported in cognitive aging appears. That is, the Old group has significantly longer latencies than the young group (or in this case, than both young groups, whose performance levels do not differ significantly). However, there is something very different in the related condition. In the case where subjects generate sentences from related noun pairs, the elderly adults are no longer the slowest to begin the sentences. The Old are still significantly slower than the Young-students, but they are significantly faster than the Young-Non-Students.

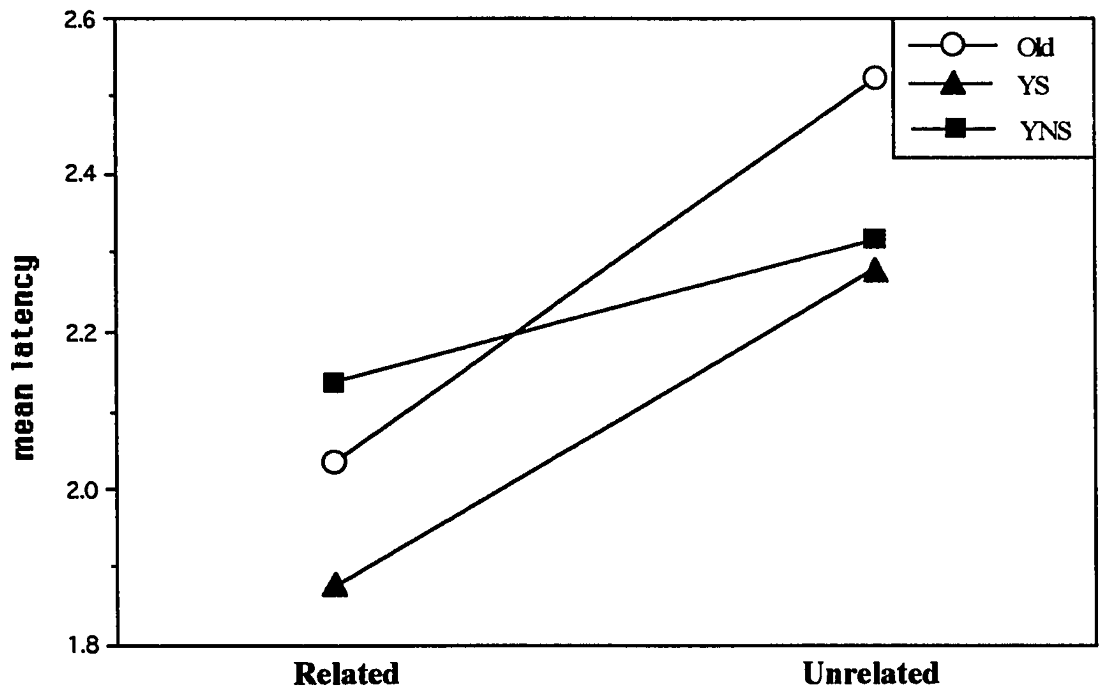

Figure 1. Mean latency for each group and relatedness condition. These latencies are collapsed across Memory load.

Number of Words Produced Per Sentence

All sentences produced by the subjects from the noun pairs were transcribed, and the number of words per sentence were counted. Again, 6 means were computed for each subject by averaging the number of words of the four sentences that were generated in each condition. Table 2 presents the mean word lengths for YS, YNS and Old subjects in each condition.

Table 2. The average number of words generated per sentence. Presented is the mean number of words produced by each group under each condition of memory load and relatedness. Numbers in parentheses are standard deviations.

	UNRELATED			RELATED		
	0	3	6	0	3	6
Young-Students	8.65 (2.02)	7.68 (1.34)	7.61 (1.28)	7.93 (1.28)	7.35 (1.49)	7.07 (1.14)
Old	9.78 (3.45)	7.97 (1.83)	7.06 (1.17)	8.53 (2.84)	7.50 (1.71)	7.43 (1.61)
Young Non-Students	8.85 (2.57)	7.36 (0.96)	7.06 (1.32)	8.04 (1.71)	6.97 (1.06)	6.40 (0.82)

A 3(Group) X 2(Relatedness) X 3(Memory load) ANOVA was computed. No significant main effect for Group occurred, but significant effects of Relatedness $F(1,51)= 23.88$, $p< .0001$ and of Memory load, $F(2,102) = 28.37$, $p< .0001$ were found. There was no significant interactions. That is, all subjects appear to decrease the number of words generated when placed under a memory load, and when generating the sentences from related (compared to unrelated) noun pairs. There is no differential effects for any of the three groups.

Sentence Duration

The total duration of each sentence produced was calculated by measuring the time of each sentence in milliseconds. This includes the beginning of the first word to the end of the final word in the sentence. The means for sentence duration for each subject group are presented in Table 3.

An ANOVA of Group X Relatedness X Memory load on sentence times showed a significant effect of Group , $F(2,51) = 6.02$, $p<.005$, a significant effect of Relatedness, $F(1,51) = 5.50$, $p<.05$ and a significant effect of Memory load, $F(2,102) = 15.91$, $p<.0001$. No interactions reached significance.

Table 3. Mean duration of sentences produced under the different conditions for each group. Time is measured in seconds. Numbers in parentheses are standard deviations.

	UNRELATED			RELATED		
	0	3	6	0	3	6
Young-Students	2.434 (1.060)	2.053 (0.626)	2.119 (0.582)	2.275 (0.591)	2.046 (0.778)	1.833 (0.438)
Old	3.135 (1.638)	2.506 (1.099)	2.412 (0.791)	2.797 (1.136)	2.389 (0.703)	2.282 (0.591)
Young Non Students	2.340 (0.979)	1.851 (0.374)	1.778 (0.399)	2.363 (0.702)	1.787 (0.387)	1.630 (0.227)

The main effects of Group and of Memory load on sentence durations were examined with Newman Keul's pairwise comparisons at the .05 level of significance. It was the older subjects that contributed to the main effect of group by producing significantly longer sentences (e.g. more time was spent on each sentence) than the two young control groups. There was no difference in the average duration of sentences produced by young persons in or out of school.

Also, sentence durations were significantly longer when there was no concurrent task. The necessity of holding six numbers in memory (as opposed to only three) did not further decrease the duration of the sentences. That is, sentence durations were no different under the memory load of three or six digits.

Speech Rate

Another measure of sentence production output is the rate at which the sentences are spoken. Dividing the number of words spoken by the time it takes to speak them for each sentence and converting that into words per minute provides the speech rate measure for any one sentence. These measures were collected for each condition providing means that were then subjected to a 3(Group) X 2(Relatedness) X 3(Memory load) analysis of variance.

This ANOVA on speech rate resulted in a significant effect of Group $F(2,51) = 11.56$, $p < .001$. Post hoc Newman Keuls' pairwise comparisons (with a .05 significance level) found that the older adults were significantly slower than the two groups of young adults. The two young groups did not differ in the speech rates generated. There was also a significant effect of Relatedness $F(1,51) = 9.07$, $p < .005$. All groups' generated sentences were spoken a bit faster under when the noun pairs were related.

Upon examining the mean speech rates under the different conditions, it is clear that it is under the memory load conditions where the faster speech rates occur. However, Memory load did not prove to be a significant factor in speech rate performance $F(2,102) = 1.70$, $p = .19$ (also there were no significant interactions among these factors). Thus, despite what we might expect, subjects do not significantly increase the speech rate of generated sentences when they have a simultaneous memory load.

The mean speech rates produced in this study, as measured in words per minute (w.p.m.), ranged from 195 to 255 w.p.m. A normal conversational speech rate is 140 to 180 w.p.m. Normal conversational speech rate differs from what we would expect to find in this study because it would include all the hesitations and pauses that occur, for example, at sentence boundaries or with word finding difficulties. The speech rates I report here are particularly intriguing when compared to the case of a speaker reading from a prepared script (such as a television newscaster), where speech rates tend to average 210 to 230 w.p.m. In this case, the speaker knows what they will say, and hence do not have to search for words. The speech rates measured in this study are comparable to those measured in speakers reading from prepared scripts. This supports the notion that subjects are planning what they will say during the latency, that is, prior to the onset of the spoken sentence.

Analysis of Covariance on Latency Measures

Under some conditions, latency to beginning a sentence may be affected by the characteristics of the sentences produced. Specifically, subjects will sometimes take longer to produce sentences that are longer. For example, when young subjects produced sentences from related pairs under a small memory load (lists of three digits), the latency measure and the word length measure (number or words) were highly correlated, $r(16) = .71$, $p < .001$.

In order to further examine the effects of Relatedness, Memory load and Age/Group on latency to sentence generation, while statistically controlling for sentence length, two analyses of covariance were performed. The first analysis of covariance (ANCOVA) was a 3(Group) X

2(Relatedness) X 3(Memory load) on latency measures with Word length as the covariate. This failed to demonstrate a significant effect of the covariate, $F(1,50) = 2.83$, $p < .10$ on Relatedness, although it did reduce slightly the effect of Relatedness, $F(1,50) = 29.83$, $p < .0001$. Thus even though related pairs produced somewhat shorter sentences than unrelated pairs and consequently may have inflated the difference in latencies, when the effect of Word length was partialled out, there was still a highly significant effect of Relatedness on sentence latencies. Furthermore, although the effect of Memory load, $F(2,101)= 14.27$, $p<.0001$, and the interaction of Relatedness and Group $F(2,50) = 4.11$, $p< .05$ were slightly reduced, they too, were still significant after word length was partialled out. I conclude then, that word length is not a major contributor to the changes in latency that occur under the various experimental conditions examined here.

The durations of the sentences produced may also be considered a measure of the length of the sentences, therefore a second 3 X 2 X 3 ANCOVA was performed on the latencies with the duration of the sentence as the covariate. As a covariate, sentence duration contributed significantly to Memory load, $F(1,101) = 7.04$, $p < .01$. While the effect of Memory load on latency was somewhat reduced, $F(2,101) = 16.63$, $p < .0001$, it was still highly significant. The more interesting finding was that when sentence duration was controlled for (there was a marginally significant effect of the covariate $F(1,50)=2.97$, $p=.09$), the Group X Relatedness interaction sustained significance, $F(2,50) = 3.35$, $p < .05$. This interaction can be seen in Figure 2 which is a graph of the adjusted cell means for the three subject groups' latency measures when sentence duration is partialled out. By examining the graph, it appears that the interaction of Relatedness X Group is likely due to the YNS demonstrating less of a difference when faced with unrelated pairs than their two comparison groups. This supports the conclusion drawn from the original latency analysis. The YS and O subjects are much faster producing sentences from related pairs than unrelated, but there does not seem to be such an effect of Relatedness for the YNS group.

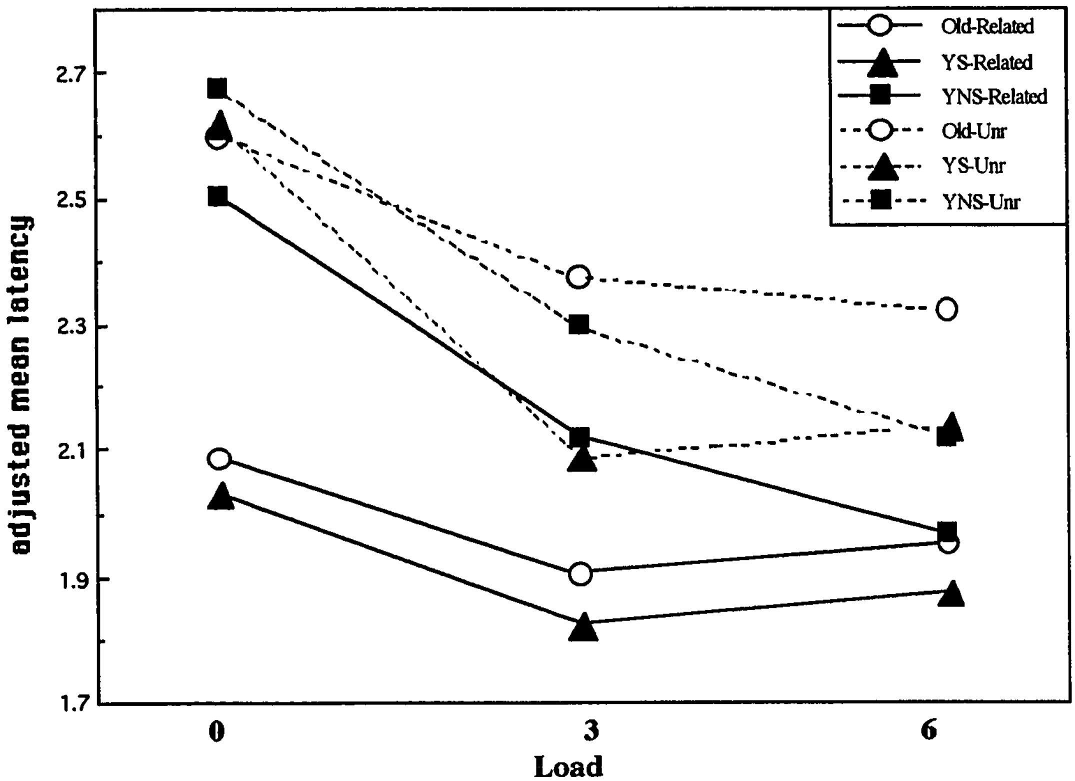

Figure 2. Adjusted mean latency for each group with sentence duration as the covariate.

Total Processing Time (TPT)

The total processing time (TPT) is a measure of the total time a subject devotes to the sentence generation portion of the task. TPT consists of both the latency to production and the duration of the sentence. That is, it is a measure of the entire time a subject spends from the moment the noun pair is presented to completion of the generated response sentence. This measure is simply computed by adding the latency to the duration (time in seconds) of the sentence. The mean total processing times were computed for each Memory load X Relatedness condition for every subject and submitted to a 3(Group) X 2(Relatedness) X 3(Memory load) ANOVA. This analysis resulted in a significant effect of Group, $F(2,51)= 3.45$, $p<.05$, a significant effect of Relatedness, $F(1,51)= 35.57$, $p<.0001$, and a significant effect of Memory load, $F(2,102)= 32.54$, $p<.0001$. The Relatedness X Group interaction approaches significance, $F(2,51)= 2.50$, $p<.10$.

The TPT for the three subject groups in each condition is shown in Figure 3. The ANOVA results were intriguing enough to warrant post hoc analyses. In examining the main effect of Group, the post hoc Newman-Keuls' comparisons (with an alpha level of .05) found a significant difference between the YS and the Old groups. The YNS sample did not differ significantly from either of the other two groups. It seems that the YNS groups' TPT devoted to each sentence tends to fall in between the amount of time devoted by a Young-student and an elderly adult.

Post hoc Newman Keuls' tests also revealed that the TPT spent during the single task condition is greater than for the two loaded conditions, and the effect of a low load versus a high load is negligible. That is, there was no significant difference between TPT at the 3 digit memory load and the 6-digit memory load.

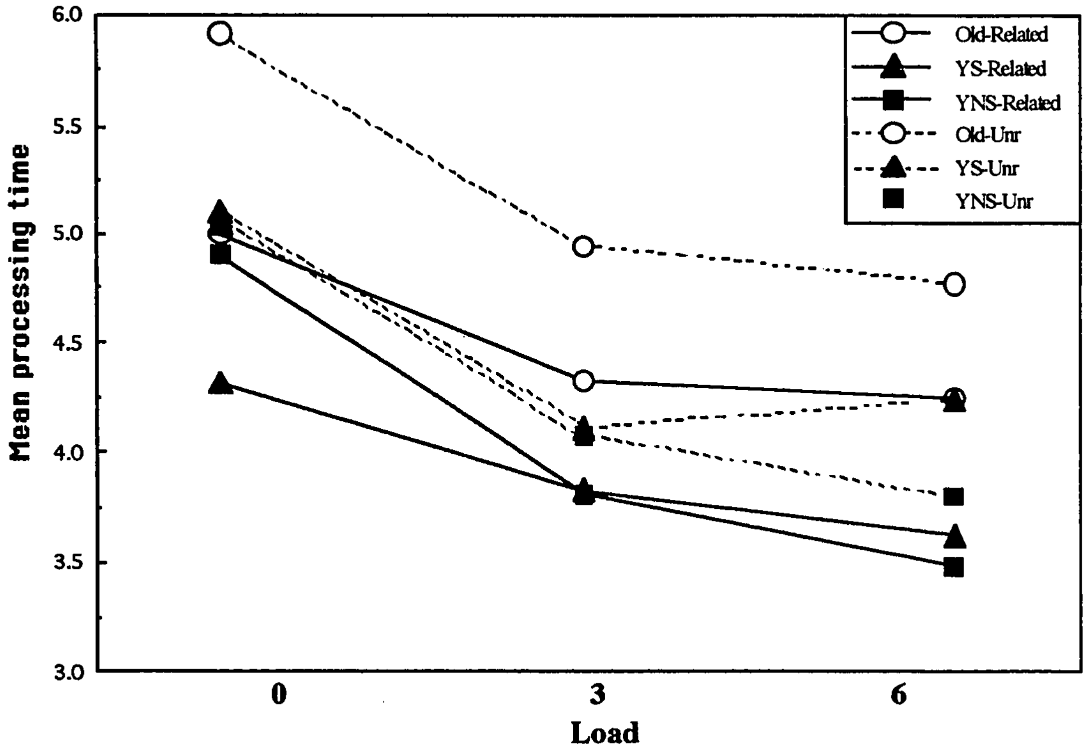

Figure 3. Total Processing Time for each group in the three memory load conditions.

Finally, to examine the trend toward a significant interaction of Group X Relatedness, the means of each group at the three levels of relatedness were examined pair by pair with the Newman Keuls' method (.05 level of significance). As was found in the latency data, the TPT devoted by the YNS subjects did not differ when generating sentences from related and unrelated noun pairs. Both of the other two groups however, significantly decreased the TPT when generating sentences from related pairs as opposed to unrelated pairs of words. Also of note in these data is that the Old subjects show significantly longer TPT for unrelated pairs than any other condition represented in the graph. Indeed, Figure 3 suggests that when generating sentences from unrelated noun pairs, the elderly adult devotes more total processing time than any other group, regardless of the memory load placed upon them.

Summary of Analyses of the Temporal Aspects of the Sentences

Memory load tends to decrease the latency to production of sentences for all subject groups tested. A memory load also effects the number of words generated per sentence, and decreases total processing time devoted to each sentence. Memory load does not have an overall effect on the rate at which the subjects speak the sentences (as measured in number of words spoken per minute). Although a concurrent task leads to reliable change in many of the characteristics of the sentences produced, these changes are similar across the three subject groups tested. That is, there is no differential effect of memory load on the characteristics of the sentences examined thus far for the three groups.

Relatedness of the noun pairs, on the other hand, tended to show differential effects between the subject groups. It is not, as we usually experience in aging research, the older adults who are showing a differential performance decrement in respect to the younger groups; it is the group of younger adults who are not currently in school who show the divergent pattern. This interaction appeared in the latency and the total processing time measures.

The ubiquitous finding of the elderly adult providing the slowest or most reduced performance was evident in these measures. This was particularly interesting in the case of the latency to production, where they were the slowest group if faced with an unrelated noun pair, but were not the slowest group if producing a sentence from a related noun pair. That is, an older adult seems to be particularly slow to initiate the production of a sentence when that sentence must connect an unrelated pair of words. In the case of creating a sentence from a related pair of words, the older adult's initiation to production is quite similar to any younger person.

Further evidence of slower performance was found when the rate at which the sentences were spoken was examined. The elderly sample did speak the sentences slower than the two comparison young samples. That is, the speech rate of the generated sentences was significantly faster for young adults than for old in this study.

The characteristics of the generated speech examined thus far relate to the temporal aspects of the sentences produced. There is another way of examining the speech output that allows for a qualitative analysis, and this measure will be examined next.

Information Content of the Generated Sentences

Information can be represented in terms of propositions which are "idea units". Speech then, may be broken up into propositions to form a measure of how much information is conveyed. A proposition consists of a predicate and it's argument(s). For example, the sentence *The dog barked at the owl* is a sentence that contains two propositions. One "idea" is that *the dog barked.* The fact that the dog barked *at the owl* is the second idea conveyed in that sentence (the dog could have barked *at John* or *at the moon*).

The sentences in this study were scored for propositional content using the Kintsch and Van Dijk system (1978) that is best delineated by Turner and Green (1977) and Bovair and Kieras (1985). This provided a numerical measure for the information content for every sentence produced, in terms of the number of propositions produced. With these scores, the search was on for any age or group differences in the amount of information generated under the different conditions.

Each of the sentences produced by the subjects was 'propositionalized' and the mean number of propositions for each condition were calculated and then submitted to an ANOVA. The resulting means for each condition for the YS, YNS and Old groups are presented in Figure 4. The data presented in Figure 4 represents the average amount of information generated across the various conditions.

The condition during which the subjects were producing sentences with no concurrent memory load is represented by the means plotted in the far left portion of Figure 4. This condition represents the most 'real world' condition tested. That is, let's consider the question: If subjects are allowed to generate speech with no simultaneous task, what do they do ?

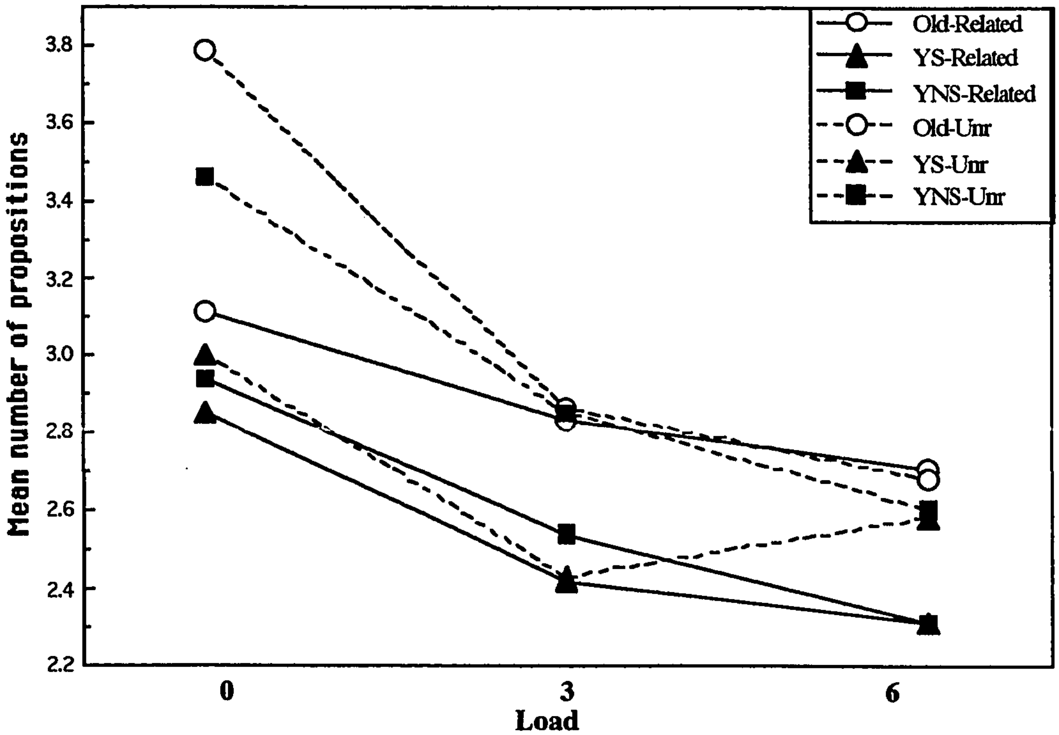

Figure 4. Mean number of propositions produced by each subject group in the three memory load conditions.

Looking at this basic condition, that is under no simultaneous memory load, it is clear that all subjects need to use more propositions to connect two unrelated words than they do to connect two related words. This is true whether you are young or old, in or out of school. That is, all subjects produce more information when they must connect a pair of words such as RABBIT-DOLLAR than they do when they are connecting STUDENT-TEST.

If subjects are generating a sentence from an unrelated pair of words, it is the old subjects who produce the most informative sentences as measured in number of propositions. That is, the older adult tends to produce a sentence that incorporates the most information. The group of Young-non-students produce sentences that are more informative than the college students, but not nearly as informative as the Old. It is the young-students who tend to produce sentences with the smallest amount of information, or propositions.

A 3(Group) X 2(Relatedness) X 3(Memory load) ANOVA resulted in a significant effect of Relatedness, $F(1,51) = 16.39$, $p < .001$ and a significant effect of Memory load $F(2,102) = 22.09$, $p < .0001$. There was no main effect of Group nor any interactions of these variables. Figure 4 suggests that the young students and older adults are performing very differently under the basic condition of no memory load: so it appears that the Old and YS are the two groups with the most divergent performance at baseline. The next step was to perform an analysis with the young-students and elderly adults groups.

When submitted to a 2 (Group) X 2(Relatedness) X 3(Memory load) ANOVA the Old and Young-students provide a complicated story. Again, there are significant effects of Relatedness $F(1,34)= 8.22$, $p<.01$ and Memory load $F(2,68)= 13.57$, $p<.0001$, and no main effect of Group, however, two interactions showed a trend toward significance. These were Relatedness X Memory load, $F(2,68)= 2.80$, $p=.0680$, and the three way interaction of Relatedness X Memory load X Group, $F(2,68)= 3.60$, $p=.0535$. In order to see this more clearly, Figure 5 is a graph of the number of propositions produced by the Young-students and

Old adults under the various experimental conditions.

Indeed Figure 5 shows clearly that the young-students and the elderly are producing the greatest amounts information for unrelated noun pairs when there is no simultaneous memory load. However, when placed under a memory load, the older adults no longer show an effect of relatedness of the pairs. Also it appears that under all conditions, the older adults are producing more information as measured in number of propositions in comparison to the YS group.

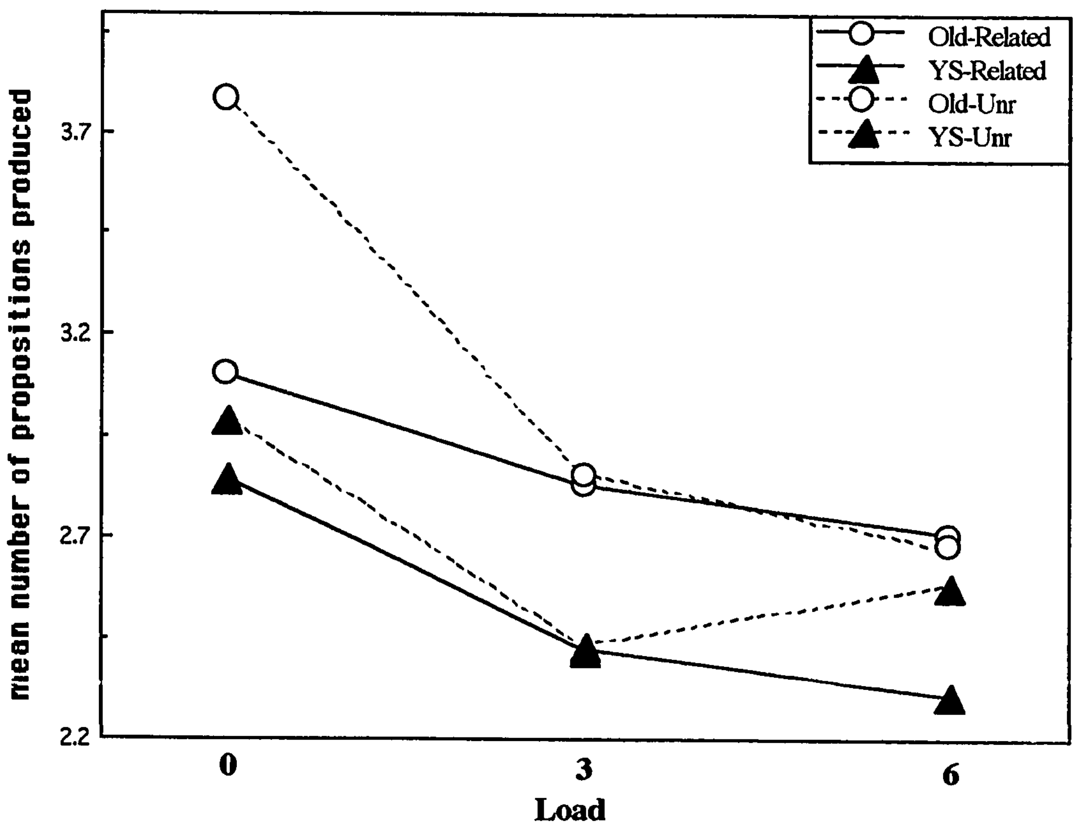

Figure 5. Mean number of propositions produced by the elderly and the young-students.

Referring back to Figure 4, which includes all three subject groups, the YNS group is performing somewhere in between the other two groups. That is, the sentences generated by this young-non-student sample are not as informative as those generated by the elderly; however, the sentences are more informative than those generated by the young-students.

Summary of the Information Content Analysis

Most often investigators of cognitive aging report of a slowing of response (like I report here with the reaction time/latency data and the speech rate data) or a decreased performance on the part of their elderly samples in comparison to young groups. The analyses on propositional content suggest a more encouraging story of increased performance on the part of the older adult. It was the older subjects who generated the most informative sentences when allowed ample time and an interesting pair of words to connect.

In fact, under all conditions, the elderly subjects are generating more information than the young college students. Furthermore, this increase of informational content is particularly pronounced if two conditions are met: 1) the sentence generation task does not have a competing memory load task, and 2) the sentences are being generated in response to a pair of unrelated words. That is, the Old subjects show a large effect of Relatedness when there was no memory load, but when placed under a memory load, they show no effect of Relatedness of the noun pairs, in terms of the number of propositions produced.

In general, it is the Young-students and the elderly subjects that show the most divergent performance. The information generated in each sentence by the YNS tends to be somewhere in between the amount generated by the young students and the elderly. Regardless, it is the Young-students that produce the least informative sentences in all cases. The elderly and the young subjects not currently engaged in educational pursuits produce more propositions than the young college students under every experimental condition tested.

Memory Measures

Memory for the Noun Pairs

The subjects all participated in a surprise free recall of the noun pairs presented during the main test directly after the completion of the divided attention task itself. The subjects were given as much time as they would like to write down as many nouns as they could remember. There were a total of 48 nouns presented in the test: 24 pairs consisting of the 12 related and 12 unrelated noun pairs.

The YS group recalled an average of 10.4(SD = 5.81) of the related and 11.8(SD = 3.99) of the unrelated nouns. The Old subjects remembered an average of 5.5(SD = 2.57) of the related and 6.2(SD = 2.56) of the unrelated nouns. The YNS group recalled 8.7(SD = 3.45) nouns from the related set and 8.2 (SD = 3.09) of the nouns from unrelated pairs. There was no significant differences in recall of unrelated versus related pairs, so Figure 6 shows the data after the two relatedness conditions were collapsed.

A 3(Group) X 3(Memory load) ANOVA was computed on the recall means. A significant effect of Group, $F(2,153) = 12.83$, $p < .0001$ upholds the observation that, at the very least, the young students recalled more of the nouns than did the old in all conditions. Newman Kuel's pairwise comparisons (at the .05 level) revealed that the young-students recalled significantly more words than both the YNS and the Old groups. Also, the YNS group recalled significantly more words than the elderly adults.

A simultaneous memory load did serve to significantly reduce recall performance for all groups, and this was statistically upheld by a significant main effect of Memory load, $F(2,153) = 17.01$, $p < .0001$. Post hoc Newman Keuls pairwise comparisons support the appearance of a significant recall difference occuring between no memory load and a simultaneous memory load, The fact that the words were originally presented under a high memory load (six numbers) or a low memory load (three numbers) seems to have very little effect on the recallability of these words. That is, no significant difference was found between the number of words recalled from the low versus high load conditions. There was no interaction of the factors of Memorly load and Group on the incidental recall of words..

What is most compelling about the data presented in Figure 6 is the performance pattern of the YNS group. The recall performance is virtually identical to the YS group when they are

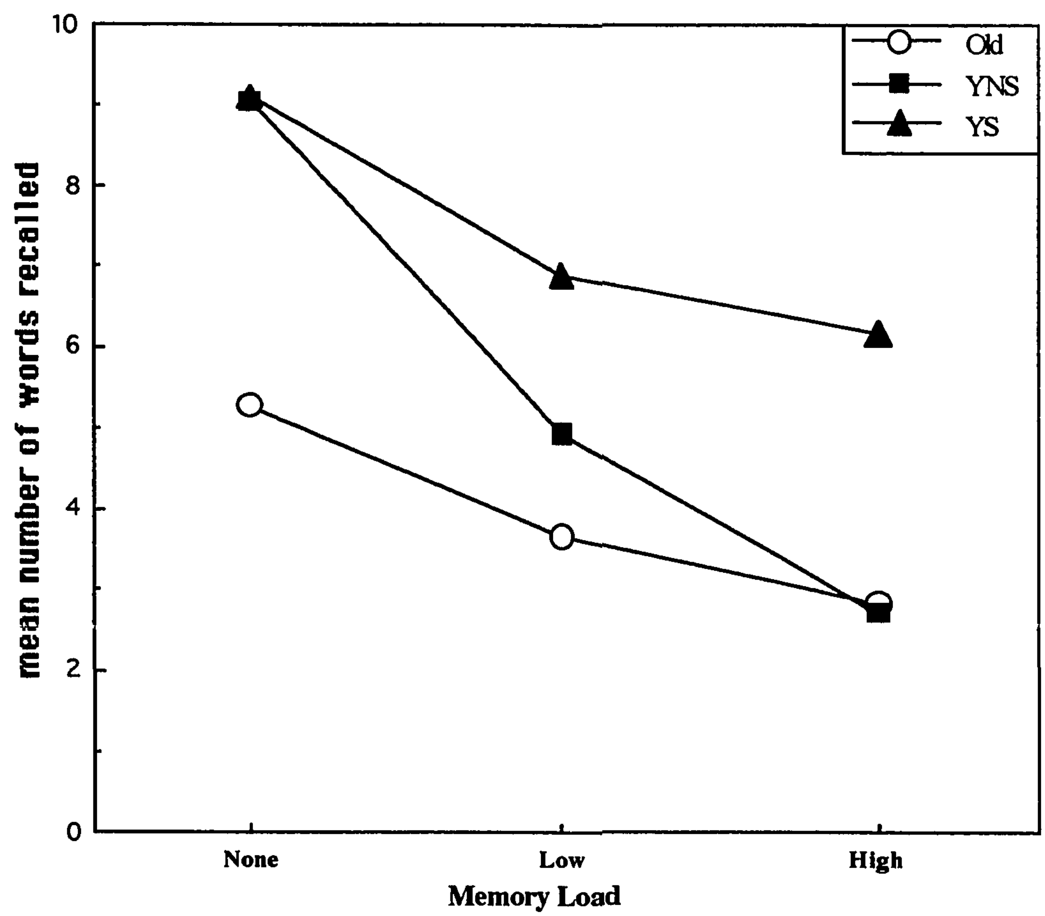

Figure 6. Incidental Word Recall

under no memory load, yet reduces to the poorer performance of the elderly adults when placed under a high memory load. In the intermediate memory load condition, this non-student young group seems to recall an average of words that falls in between the two other groups.

In order to further examine the possible interaction of memory capacity and cognitive performance, an in depth examination of the memory span measures obtained in this study is necessary.

Analysis Of Memory Spans

Span Performance

The mean spans for each subject group are plotted in a stacked bar graph to provide a visual picture of the overall scores for each group. These spans are presented in Figure 7 which shows that the Young-students had the highest Total Span score (mean= 45.59 SD= 6.65) and the Young-Non-Students on average, had nearly as high a Total Span score (mean= 41.24, SD= 3.00). Here the results show the predominant age deficit in immediate memory span, where the elderly adults had the lowest Total span score (mean=35.59, SD=4.74). This Total Span measure was submitted to a One-way Between groups analysis of variance, resulting in a significant effect of Group, $F(2,51)=9.83$, $p < .001$. Post hoc pairwise comparisons (Newman Keuls at the .05 level of significance) uphold the observation that the Old have significantly lower Total Span measure than the other two groups.

Looking at each span test individually, three of these tests showed no difference among the three subject groups tested. Forward digit, backward digit and reading spans all were found to have equivalent performance between all three samples. All other span tests showed an advantage for the two young groups in relation to the elderly adults with equal performance for these two young groups that was statistically greater than the older adult's performance levels. See Appendix D for the full descriptive statistics of the eight span tests administered in this study.

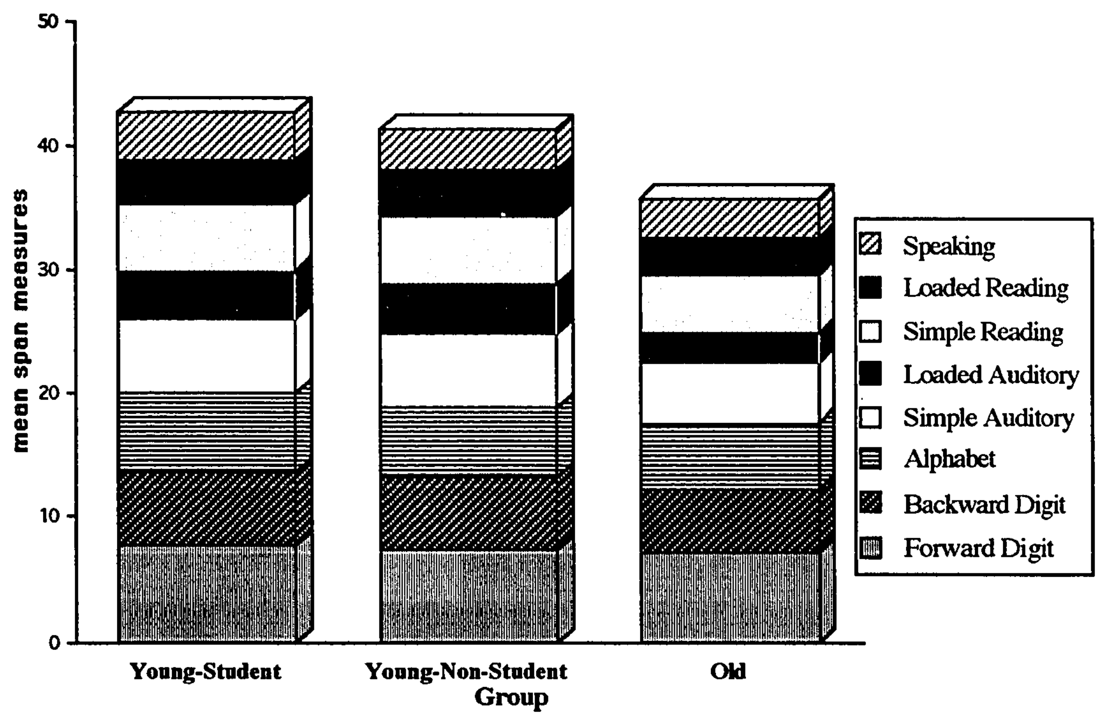

Figure 7. The eight memory span scores are presented in an additive fashion for the three subject groups.

Relationships Between Memory Spans

When examining the eight memory span tests administered in this study, there were very high relationships among all the different memory span tests administered, at least for the YS and Old subjects. Table 4 presents the intercorrelations between the eight memory spans for the Young-student sample. The Pearson correlations show very high positive relationships among all the spans. The intercorrelations among the memory span tests are also very high for the Old sample, and these data are presented in Table 5. Very strong relationships, such as is seen here, suggests that the eight different memory span tests are measuring some similar component or ability of the information processing system

The same intercorrelations among the memory span tests are presented for the YNS sample in Table 6. Although many of the correlations are in a positive direction, this young-non-student group does not demonstrate the same highly correlated pattern between the memory spans that is evident in the two other groups. First, there are only two significant intercorrelations between all the spans, and second, many of the relationships actually show a negative trend. For example, backward digit span has a negative relationship with all the spans measured except for the simple reading span.

These data are puzzling. Perhaps it is the case that the motivational demands differ among the subject groups tested here. Just why this young-non-student group would show such a different pattern in the relationship between those memory spans administered is beyond the scope of this study, but an interesting difference in performance measures that should be examined further.

Table 4. Pearson Correlations between the eight memory spans for the Young-Student group.

	Forward Digit Span	Backward Digit Span	Alphabet Span	Simple Auditory Span	Loaded Auditory Span	Simple Reading Span	Loaded Reading Span
Forward Digit Span	-						
Backward Digit Span	.44	-					
Alphabet Span	.50*	.63**	-				
Simple Auditory Span	.48*	.33	.59**	-			
Loaded Auditory Span	.60**	.44	.53	.55*	-		
Simple Reading Span	.54*	.61**	.71**	.42	.61**	-	
Loaded Reading Span	.61**	.25	.59**	.71**	.67**	.72**	-
Loaded Speaking Span	.37	.60**	.43	.49*	.54*	.42	.40

Note: * is significant at .05 and ** is significant at .01.

Table 5. Pearson Correlations between the eight memory spans for Elderly.

	Forward Digit Span	Backward Digit Span	Alphabet Span	Simple Auditory Span	Loaded Auditory Span	Simple Reading Span	Loaded Reading Span
Forward Digit Span	-						
Backward Digit Span	.19	-					
Alphabet Span	.17	.34	-				
Simple Auditory Span	.60**	.48*	.51*	-			
Loaded Auditory Span	.41	.19	.44	.56*	-		
Simple Reading Span	.60**	.58*	.33	.81**	.46	-	
Loaded Reading Span	.09	.20	.49*	.41	.44	.28	-
Loaded Speaking Span	.40	.55*	.70**	.68**	.63**	.46	.53*

Note: * is significant at .05 and ** is significant at .01.

Table 6. Pearson Correlations between the eight memory spans for the Young-Non-Students .

	Forward Digit Span	Backward Digit Span	Alphabet Span	Simple Auditory Span	Loaded Auditory Span	Simple Reading Span	Loaded Reading Span
Forward Digit Span	-						
Backward Digit Span	.04	-					
Alphabet Span	-.35	-.08	-				
Simple Auditory Span	-.14	-.02	.62**	-			
Loaded Auditory Span	-.18	-.26	.09	.34	-		
Simple Reading Span	.06	.12	.14	.26	.32	-	
Loaded Reading Span	.30	-.17	.16	.48*	.34	.26	-
Loaded Speaking Span	.28	-.32	-.08	.27	.24	.50*	.63**

Note: * is significant at .05 and ** is significant at .01.

Since the relationships among the various spans were so strong, at least for two of the groups, it is likely that these spans are tapping a similar processing component. On the other hand, it is also possible that they are measuring separate components, for example storage capacity and processing efficiency. According to our criteria for working memory tasks (versus simple storage tasks), we assume that we have designed tests that tap different aspects of the human processing system. If this is the case, then I would expect a component analysis to separate the spans into a 'working memory' component and a 'simple storage' component. In other words, the expectation is for one factor to consist of those scores from the simple storage tests, and a second factor to consist of the scores from those spans we consider to be WM tests. In order to test these possibilities, the span scores were submitted to a principal component factor analysis.

The eight span scores for all subjects were entered into a principal component factor analysis which resulted in one principle component factor. The eigen values and factor loadings are reported in Appendix E. The result of a single factor suggests that the span tests are indeed measuring some similar component or capacity of the cognitive system.

This aspect of the memory spans needs further analysis. One way to do this is to directly examine the difference between the spans designed to tap primary memory and those designed to tap working memory abilities. That is, we can hand pick those scores from the tests that are assumed to test working memory and separate them from those that are defined as simple storage tasks. After separating the two types of memory spans, test for performance differences between those simple spans and WM spans across the three subject groups.

The premise here is an assumption clearly stated in Wingfield et al. (1988). That is, we assume that we measure pure storage capacity for an individual when we administer "simple" memory tests such as forward digit span, or recall of simple word lists (as is tested in both the simple reading span and the simple listening span here). However, when we simultaneously tax the processing system while we require our subjects to store items, we consider the test as measuring working memory ability. Those tests considered to tap working memory in this study were the alphabet, backward digit, loaded auditory, loaded reading, and loaded speaking spans.

For this reason, the five tests of working memory were averaged together to form one measure of WM termed '**loaded** span'. The simple storage task scores were averaged for each individual to create a '**simple** span' measure.

Submitting these new scores to a 3(Group) X 2(Span Type:Simple vs. Loaded) ANOVA resulted in a significant main effect of Group, $F(2,51) = 9.70$, $p < .001$, a significant main effect of Span type, $F(1,51) = 719.38$, $p < .0001$, and no interaction of these two factors. Newman Keuls' pairwise comparisons (reported at the .05 level of significance) revealed what the graph suggests, that the older adults overall, are the group that have significantly worse performance than the other two groups. The performance levels of the two young samples do not differ statistically.

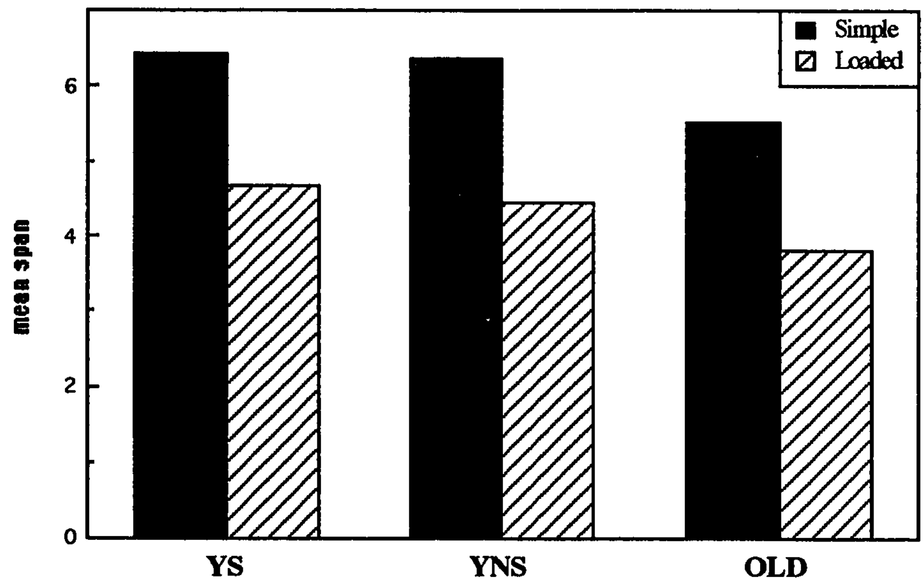

Figure 8. Average simple storage and loaded (WM) spans for the three subject groups.

It's important to keep in mind that finding a mean level difference between the simple storage and working memory tests will not provide an answer as to whether the working memory tests are actually tapping something different than their more simple span counterparts. It is certainly the case that the additional necessity of simultaneous processing or manipulation of information during storage (as is required in the WM tests) might only serve to reduce performance level, but in no differential manner for any individual. If this is the case, then the two types of memory span tests would, indeed, be highly correlated for each individual. The correlations reported in Tables 4, 5, and 6 appear to suggest this. The principle component factor analysis supports this notion as well (see Appendix E). At least, this is likely to be the case for the YS and Old, although the case of the YNS group is unclear.

Returning to the results of Wingfield et al. (1988), it has yet to be concluded that indeed, the older adult does have a particular deficit with working memory tasks. The jury is still out, and the literature has mixed results on this question as far as the measurement of working memory goes. Therefore, I will pursue this issue further.

Further Analysis of Span Performance

A second method for examining the hypothesis that working memory tests somehow differ from simple storage tests will allow for possible replication of the results found by Wingfield, Stine, Lahar and Aberdeen (1988). These investigators report a differential decrease in performance of the older adults on a test of working memory in comparison to a group of young college students. They report no difference in the scores these two groups achieved on forward digit span and a small difference on a simple word span. The differentially poorer performance level of the elderly group appeared in the loaded auditory span test. Since the present study used identical tests to those reported in Wingfield et al.(1988), I directly compared the results found here for the comparable subject groups (young-students and old adults) and span tests.

I submitted the young-student and the elderly adult groups to the analysis procedure used by Wingfield et al.(1988). The spans that were analyzed are the forward digit span, the simple auditory span and the loaded auditory span, and the means for the two groups on these three memory tests are presented in Figure 9.

Looking first at the forward digit span scores, the young-students did achieve a slightly higher mean forward digit span (mean = 7.72) than the elderly (mean= 7.11)[4], however, there was no significant difference between the two groups, $t(1,34)= 1.91, p > .05$. In the Wingfield et al. study, the two subject groups achieved virtually identical mean forward digit spans. Although the older adults I tested are a little worse in digit recall performance than the young, these differences are not significant, hence so far, our results are consistent.

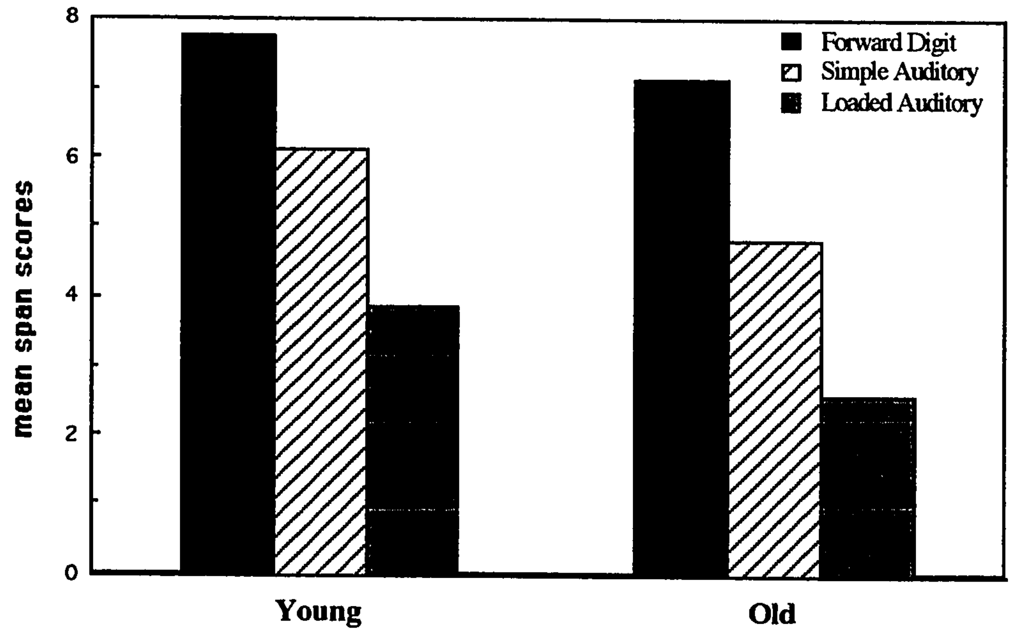

Figure 9. Mean scores of three memory spans: forward digit, simple auditory and loaded auditory for the Young-student and Old groups.

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[4] See Appendix D for descriptive statistics on forward digit span for all three subject groups.

The next step was to submit the 'storage' based simple auditory word span and the 'WM' based loaded auditory spans to a 2(Age Group: Young-students and Old) X 2(Load: simple and loaded tasks) ANOVA. Certainly a large age decrement is evident in the performance on these tasks, and the analysis resulted in a significant main effect of Age Group $F(1,34)=19.82$, $p < .001$. Also a significant main effect of Load $F(1,34)=214.57$, $p < .0001$ was found. That is, all subjects achieve lower scores on the *loaded,* or working memory, span tests. There was, however, no significant interaction of Age Group X Loading, $F(1,34)=.01$ $p < .9289$, or in other words, there is no differential decrease for the Old subjects as we introduce a simultaneous processing aspect to the storage task.

These results fail to replicate those reported by the Wingfield et al. study. The elderly subjects examined here do not show a differential decrease in performance when the task includes what we define as a 'working memory' component. There is a significant decrease in performance for all subject groups when WM involvement is necessary, but this decrease is not a proportionally greater decrease for the elderly adult. Despite the expectation of an Age interaction, it was not found here.

When analyzed separately, the reading span scores produced the same patterns as those shown for the auditory spans. The speaking span scores also showed decreased levels of performance for the older adults, but no particular differential decrease when compared with a simple memory storage task in the same domain. The results from these span measures are consistent in showing an age decrement, that is the old do worse on all the span measures tested. In fact, the old do worse on both the simple and the loaded spans tests. However, they do not perform differentially worse than the younger groups.

Relationships Between Task Performance And Memory Spans

A final aspect of these data that needs addressing is whether memory performance is predictive of task performance in the main experiment. There is the possibility that spans could be predictive of one or both of the two tasks required of the subjects in this experiment. The relationships between the spans and two separate performance measures will be examined The first performance measure will be the digit recall, and the second will be the number of propositions produced per sentence.

If we were to consider memory for the digits while producing a sentence to be an instance of a "loaded" or working memory span test, then we should expect high correlations between subjects span measures and digit recall measures in this study. This can be examined by looking at the correlations among the measures.

First of all, we must recall that the performance on the three digit lists for all subjects groups was near one-hundred percent, which means this data will not demonstrate a strong relationship with any measure. So, in order to determine if there is a relationship between a subjects memory ability and their performance the cognitive task, the dependent variable from the main task will be the percent correctly recalled from the six digit lists. These digit lists were held in memory while the subjects produced a sentence, and so there is a storage component of holding the numbers, and a simultaneous processing component of creating and speaking a sentence. For each subject, the digit recall measures were separated into those occurring in the related condition and those occurring in the unrelated condition. Since the sentences tend to have a greater amount of information, and are often longer when they are produced to connect an unrelated pairs of words, we expect poorer digit recall performance in that condition. Indeed that is the case (refer back to pages 55 and 64).

The Pearson correlations for the young-student subjects are presented in Table 7, and all the relationships are positive, as we would expect. However, it does not seem to be the case that the tests designed specifically to tap WM are any more (or less) predictive of amount of digits recalled. The older subjects also show a strong relationship between some of the memory spans measured and the digit recall performance. This trend is toward positive correlations, although the relationships do not appear as clearly predictive as the young-students.

When looking toward the Non-student sample, only one test of memory span had a significant relationship with digit recall, and that was the loaded reading span test, $r(16)=.48$, $p<.05$. No other correlations reached significance, and many leaned toward a negative trend.

Table 7. Pearson Correlations between the Digit Recall and Memory Spans of the Young-Students.

	Digit Recall Related Six	Digit Recall Unrelated Six
Forward Digit Span	.75**	.57*
Backward Digit Span	.58*	.16
Alphabet Span	.50*	.13
Simple Auditory Span	.56*	.55*
Loaded Auditory Span	.56*	.56*
Simple Reading Span	.56*	.36
Loaded Reading Span	.48*	.65**
Loaded Speaking Span	.74**	.40
Simple Span	.77**	.61**
Loaded Span	.70**	.47*
Total Span	.75**	.54*

Note: * is significant at .05 and ** is significant at .01.

Table 8. Pearson Correlations between Digit Recall and Memory Spans for Old subjects.

	Digit Recall Related Six	Digit Recall Unrelated Six
Forward Digit Span	.33	.41
Backward Digit Span	.43	.25
Alphabet Span	.40	.20
Simple Auditory Span	.70**	.45
Loaded Auditory Span	.48*	.29
Simple Reading Span	.62**	.53*
Loaded Reading Span	.37	-.09
Loaded Speaking Span	.47	.39
Simple Span	.63**	.53*
Loaded Span	.61**	.30
Total span	.69**	.44

Note: * is significant at .05 and ** is significant at .01.

Table 9. Pearson Correlations between the Digit Recall and Memory Spans of the Young-Non-Students.

	Digit Recall Related Six	Digit Recall Unrelated Six
Forward Digit Span	.17	.01
Backward Digit Span	.07	.36
Alphabet Span	-.38	.14
Simple Auditory Span	.21	.08
Loaded Auditory Span	.24	.13
Simple Reading Span	-.08	.10
Loaded Reading Span	-.09	.48*
Loaded Speaking Span	-.24	.32
Simple Span	.09	.12
Loaded Span	.34	.08
Total Span	.25	.11

Note: * is significant at .05

Finally, the relationship between performance in the sentence generation task and memory spans was explored. It was expected that the span tests that were most closely tied to the performance measures would show the highest relationships with the task performance. Specifically, the speaking span test was expected to show a higher correlation with the number of propositions produced in the sentences than the other span measures. Table 10 includes the Pearson correlations between all the span test scores and the number of propositions produced in each condition for the Old sample. The relationships suggest that the speaking span test is the best predictor for this aspect of the task. No other span tests are significantly related to the amount of information that is produced under memory load. It is interesting that these

Table 10. Pearson Correlations for Old subjects between Memory Spans and the Mean Number of Propositions Produced.

	Propositions Produced					
	Related			Unrelated		
	0	3	6	0	3	6
Forward Digit Span	-.37	-.37	-.33	-.20	-.28	-.15
Backward Digit Span	.08	.01	-.19	-.09	-.08	-.06
Alphabet Span	-.12	-.28	-.26	-.30	-.40	-.20
Simple Auditory Span	-.25	-.26	-.45	-.20	-.27	-.42
Loaded Auditory Span	-.20	-.25	-.17	-.10	-.29	-.33
Simple Reading Span	-.18	-.04	-.34	-.04	-.10	-.15
Loaded Reading Span	.05	-.11	-.28	-.11	-.27	-.21
Loaded Speaking Span	-.23	-.50*	-.51*	-.40	-.50*	-.44

Note: * is significant at .05.

relationships are only significant in the case where there is a simultaneous memory load, and not in the case where the sentence formulation task was a single task. These results fit well with the expectations that a loaded span test that taps a similar domain as is tapped in the task at hand will be the best test for predicting performance levels.

It does seem to be the case that the loaded speaking span, a measure designed to test WM in the domain of speaking is the best predictor of performance on a speaking task for older adults. However, this does not hold true for either young-students or for young-non-students. Tables 11 and 12 present these same correlations for the other two subject groups tested. In Table 11 it is clear that no span tests show a high relationship with sentence information generated for the YNS group, and Table 12 demonstrates a similarly disappointing finding for the typical young control group of college students.

Table 11. Pearson Correlations for Young-Non-Student Groups between Memory Spans and Mean Number of Propositions Produced.

	Propositions Produced					
	Related			Unrelated		
	0	3	6	0	3	6
Forward Digit Span	.02	-.14	-.01	-.19	.09	.01
Backward Digit Span	-.01	-.18	-.12	-.30	-.29	-.30
Alphabet Span	.04	.00	-.10	-.21	.13	.27
Simple Auditory Span	-.27	.01	.33	-.20	.04	-.27
Loaded Auditory Span	.09	.06	.00	.14	.34	-.02
Simple Reading Span	.27	.20	-.30	.15	.03	-.34
Loaded Reading Span	.01	-.27	-.04	-.33	.03	-.21
Loaded Speaking Span	.27	-.01	-.21	.04	.07	-.02

Note: * is significant at .05.

Table 12. Pearson Correlations for Young-Students between Memory Spans and the Mean Number of Propositions Produced.

	Propositions Produced					
	Related			Unrelated		
	0	3	6	0	3	6
Forward Digit Span	.39	.43	.09	.12	.32	.34
Backward Digit Span	-.13	.36	-.05	.08	.29	.41
Alphabet Span	-.24	.20	.02	.10	.19	.36
Simple Auditory Span	.18	-.11	.00	.37	-.02	.14
Loaded Auditory Span	.29	.54*	.08	.19	.42	.25
Simple Reading Span	-.08	.27	-.09	.19	.25	.41
Loaded Reading Span	.28	.10	.02	.44	.10	.23
Loaded Speaking Span	.04	.06	-.24	-.01	.00	-.03

Note: * is significant at .05.

Discussion of Experimental Results

There were perhaps as many interesting age similarities as there were age differences in the data presented here. Many of the variables examined show the classic finding of slower or decreased performance among the older adults as they are compared to a younger sample. The elderly provided the longest sentence durations, and related to this measure, the slowest speech rates. A slower speech rate in aged individuals has been reported (Kynette, Kemper, Norman & Cheung, 1990; Ramig, 1983; Ryan & Burk, 1974; Smith, Wasowicz & Preston, 1987), and is suggestive of a general cognitive slowing with age (Salthouse, 1985). The elderly performed worse in all memory span tests administered, and also recalled the smallest percentages of digits that they were to remember while generating sentences. Although the elderly showed a consistent trend of worse performance than the other two groups, this performance decrement was only significant in some of the variables examined. Not only that, there were certain aspects of this study where it could be (and will be) argued that the older adult actually out-performed the younger adults.

Increasing Memory Load

It has previously been shown that for young adults a memory pre-load affects latencies to generating sentences from two words (Power, 1985). Additional processing demands during speech production significantly decreased the time used by the speakers to formulate each sentence. The results of this experiment show that this is the case for all three subject samples tested.

No age differences have been reported in sentence formation time when young and old adults are asked to generate sentences from pairs of words (Nebes & Andrews-Kulis, 1976).

The results of this study are consistent with that finding in that there was no main effect of group on the latency data. That is, overall older adults form sentences just as rapidly as young adults. Nebes and Andrews-Kulis (1976) however, examined this phenomenon only in the case where the subjects could devote all their processing resources to the task. I expected that by adding processing demands, the older adult would be differentially slowed.

The hypothesis of a predicted increase in speech production planning time for the older adult has been particularly devoid of data (Light, 1988) and was directly put to the test here. That is, performance was expected to change even more drastically for the old group in relation to the younger groups when placed under memory load. There is ample evidence to suggest that even very healthy and active elderly adults have decreased cognitive processing resources in comparison to young adults (e.g. Craik & Byrd, 1982), or smaller working memory systems (e.g. Wingfield, et al., 1988). And in fact, the memory spans of the older adults in this study were much smaller than those measured in the young control groups. Any decrease in available processing resources (such as WM capacity) should lead to a more pronounced performance decrease when additional resources are being called upon by the task or tasks at hand (e.g. Tun, Wingfield & Stine, 1991; Navon & Gopher, 1979; Kahneman, 1973). By testing a sample of elderly adults and two samples of younger adults, it was expected that the increase in the initiation time of the sentences under memory loaded conditions would be particularly large in the case of the older adults.

The results from the present study show that the older adult is in no way differentially slowed when faced with a memory load of random digit lists. That is, for the latency to sentence generation data, the predicted differential slowing under memory load was not found for the elderly in this study. It seems that the older adult is indeed as quick to concoct a sentence as any younger person, and more importantly, both groups can do so equally well if burdened with additional task demands.

It is certainly the case, however, that differential performance among the groups (as was expected with the elderly under memory load) would appear in other aspects of the sentences generated, and not in the formulation time. Increasing the load on working memory may not influence the initiation time for the sentences, but may show it's effect on sentence quality or length. It could be that the older adult takes no longer to create a sentence, but the resulting sentence is somehow different. For example, it may be that the older adults sentences that are produced under a memory load are shorter or more likely to have errors.

There was a resulting set of 1,296 sentences generated for analysis in this study. All were judged as adequately grammatical and all successfully incorporated the two words presented. There were only three cases of sentences that were not obviously grammatical. Interestingly, each subject group provided one of these three cases. A case of a probable word reversal occurred when a YNS subject generated the sentence *The table wouldn't open because of the door*. A drop-leaf table could certainly explain this response to the noun pair TABLE-DOOR, so this was judged as grammatical. Another interesting sentence where one has to stretch their imagination in order to understand the semantics behind the sentence is: *The rabbit ran all over the dollar*. This sentence was generated by a YS subject in response to the noun pair RABBIT-DOLLAR. Both of these sentences were generated under the heaviest memory load conditions, that is, they had to simultaneously hold six numbers in mind while generating the sentence. There was one unusual sentence produced by an old subject, and this occurred in response to the noun pair STUDENT-TEST. The elderly adult in this case, formulated the sentence *I flunked the student test*. Again, by stretching one's mind, and assuming that student is an adjective, this can be considered a grammatical sentence.

So it does not seem to be the case that more errors occur for the old subjects than any other group. It is still possible that other characteristics of the sentences generated could be prone to change due to an increased memory load of digit lists. And once again, this would be especially interesting if any differences found were particularly pronounced for the older group in the memory load conditions.

Measures of sentence duration, number of words per sentence, speech rate of the sentences, and total processing time devoted to each sentence all failed to show an Age X Memory load interaction. That is, young and old are equally likely to create a shorter sentence if they have a simultaneous task of remembering digit lists as compared to when they can make up a sentence with no concurrent task. Also, all the subject groups are likely to speed up the formulation times if they have a concurrent task at hand. It must be concluded that the loading of working memory does not prove to be differentially damaging to an older adults' sentence production as compared to young adults.

In summary, WM loading decreased everyone's performance, but the expected finding of this posing a particular problem for the old did not arise. It is true that loading storage demands onto the processing system in the form of a digit recall task does cause some changes in sentence production. People are very adaptive, and when under load, shorten the speech output, and speed it up a bit. It just wasn't particularly so for the elderly. However, there are many ways to tax the human processing system that might indeed lead to a particular problem for the elderly, such as increasing task complexity (e.g. Craik, Morris & Gick, in press). This Age X Memory load prediction could still hold true when we consider the other aspect of task difficulty introduced in this research.

Relatedness /Task Complexity

Not only can a secondary task of digit recall place a load on the human cognitive processing system, but increasing the primary task difficulty of sentence generation can do so as well. Here the task difficulty or demands were manipulated within the sentence generation portion of this experiment. During half the trials the subjects had a very easy task of formulating sentences that included highly related noun pairs, but for the remaining half of the trials they were required to make up sentences that incorporated two unrelated words. Certainly it is much easier to make up a sentence from DOCTOR-PATIENT than it is to create a sentence which uses both BABY and DUST. This effect of relatedness of the noun pairs can be considered to increase the load on the processing system, or increase the complexity of the task.

I have found that when people are presented with an unrelated pair of words to incorporate into a sentence, they will take longer to initiate the sentence than when they must generate a sentence from a related pair of words. This relatedness effect has been consistently reported in the literature (Power, 1985; Rosenberg, 1977) and is considered to be the time necessary for semantic planning of the sentence. Power (1985) and Goldman-Eisler (1968) argue that it takes conscious planning to make the decisions regarding what will be spoken during this semantic planning of an utterance (Yngve, 1960). The lexical, syntactic and phonological decisions are, on the other hand, automatic (see for example Ferreira & Clifton, 1986; Fodor, 1983; Martin, 1987; however see Ferriera, 1991 for a different view on phonological encoding). The semantic processing involved in formulating a sentence is assumed to make use of the general workspace of working memory. As early as 1960 Yngve has argued that speakers make the necessary decisions regarding what they will say during the latency to production of sentences (Yngve, 1960). The relatedness effect shown in the results of the experiment presented here support the findings of Power (1985) in concluding that semantic processing occurs prior to initiation of a sentence.

This means that prior to sentence initiation, the speaker must pick the topic (if it is not already assigned), choose the subject and object relations and assign a phonological encoding (cf., Ferreira, 1991; Levelt, 1989). Rosenberg (1977) suggested that the speaker need only activate one semantic connection (or proposition) from long term memory when they generate a sentence from a related word pair. Once that 'connection' is activated, they need only to produce the sentence. It takes longer in the case of unrelated words, because they actually have to generate a connection or relationship between the two unrelated words, since it is very unlikely that there is already a connection 'in store'. A similar argument is that the related nouns are closer in the semantic network of the individual, hence reaction times will be shorter than when finding a link between unrelated nouns.

Regardless of the explanation for the relatedness effect, conscious planning decisions will place demands on working memory. If the unrelated case requires a person to generate a relation, this may or may not be easier for the older adult. On the one hand, they may have more idiosyncratic connections built due to the years of experience, and then the unrelatedness of the noun pair would present no particular difficulty for them.

It is also possible that due to a slowing of the system, the older adult will take longer to scroll through their semantic network, and find a relation between two unrelated words. Then we would expect a longer sentence initiation time for the elderly compared to the young subjects (see Rosenberg, 1977). However, there is ample evidence that suggests that the older adult does not have any decrease in semantic activation time (Bowles and Poon, 1985; Howard, Shaw & Heisey, 1986) and no changes occur with spreading activation across age (Balota & Duchek, 1989; Burke & Harrold, 1988). This left an unclear expectation regarding the possibility of a differential relatedness effect for the elderly group, because there is tremendous evidence that suggests that age differences are exaggerated with increased task complexity (e.g. McDowd & Craik, 1988).

Also, the speech production of older adults has been hypothesized to be particularly vulnerable to high processing demands. For example, the variable of complexity in sentence production has been specifically implicated as one that places a load on memory (e.g., Kemper, 1988; Klatzky, 1988). In this study, complexity was introduced by requiring subjects to form sentences from both related pairs of words and from more complex unrelated pairs of words. Along with the hypothesis that WM capacity is reduced with age, this led to a clear expectation that fluent speech production in the elderly would be differentially changed by increasing the primary task complexity.

Like the young-students, the elderly were slower to create a sentence from an unrelated pair of words than they were from a related pair of words. Interestingly, the young-non-students showed very little effect of relatedness. That is, the latency to producing the sentences for this non-student sample was only slightly larger when they were producing a sentence with two unrelated words instead of two related words. In fact, it was this lack of an effect of relatedness for the young-non-students that contributed to the Age/Group X Relatedness interaction seen for latency.

It was in the condition of generating sentences from unrelated nouns that the old had extremely large sentence initiation times, significantly larger than the two younger groups. The elderly were certainly the group that showed the very longest sentence initiation times with unrelated words. These large initiation times for the old are probably due to the fact that they generated such informative sentences, as measured in the number of propositions.

This is perhaps the most intriguing of results from this study, that is, the finding that the old adults produced the most informative sentences in relation to their younger counterparts. If given ample time and an interesting topic, they are producing the very most informative sentences of all.

Everyone in this study produced more propositions per sentence when creating them from unrelated pairs of words, as compared to related pairs of words. All subjects also tended to produce less informative sentences when they were faced with a simultaneous task of remembering digit lists. But in the case that represents the most nearly real world situation tested, the older adults prevailed. They produced the very most informative sentences of all when they were given unrelated noun pairs to incorporate into those sentences. The young-non-students also produced relatively more propositions per sentence in this single task condition. The young-students, however, barely produced any more informative sentences than they did in any other condition.

So when given the time and opportunity, the older adult tends to produce more propositions per sentence than their younger counterparts. A young college student does not use this opportunity, it appears, to do anything more than they need to get by. And in the case of a young person drawn from the community, they also tend to take advantage of the opportunity to be interesting, but not to so great a degree as the elderly.

It has been reported that old adults are more interesting in terms of their speech production (Albert, 1981; Kemper et al., 1989; Obler, 1980; Obler & Albert, 1985; Smith, Rebok, Smith, Hall & Alvin, 1983), but much of this evidence is anecdotal. Certainly, the evidence has constraints other than normal language production. For example, Smith et al (1983) provide this interpretation from a task that requires older adults to re-tell stories that were told to them. It is possible that the more interesting stories from the older adults were strategic ploys to hide memory problems.

Walker, Roberts, and Hedrick (1988) report an increase in vocabulary diversity in aging adults spoken discourse and Bromley (1991) reports the same effect of increased vocabulary diversity with age in samples of written language production. The Walker et al. study also found that the elderly produced shorter utterances than the younger sample. This was not the case in the present study. Here there is no evidence for the older persons to produce shorter utterances than the young. Indeed, these results suggest that they produce longer utterances, especially if they are not required to perform a concurrent task.

One final thing that needs to be noted here, the YNS group were the least affected by task complexity. That is, the relatedness of the noun pairs had a significantly smaller effect on their sentence formulation times than in comparison to both the old and the young-students. This is particularly interesting because what if we had just tested this sample in comparison to the old? In that case, we would have found a differential effect of complexity (relatedness effect) for the two groups. This suggests that the sample of young adults chosen has some very important theoretical implications. In the same notion, if I had just compared the non-student and the student young groups, I would have seen a Group X Complexity interaction as well. This suggests that the young students in psychology classes may not at all be representative of the population of young adults in general. This issue will be examined in the next chapter.

To summarize thus far, there is no clear finding that the old are differentially affected by one form of difficulty (task complexity) or another (memory load). Craik, Morris and Gick (in press) have analyzed a number of results into the general notion that task complexity will show a differential age effect, but memory load will not. These results do not support the possibility that complexity increases age differences in a sentence production task. Although the old are slower in nearly all cases, there is no differential effect when we either ask the person to hold lists of numbers in memory, or when we increase the complexity of the task at hand.

Although the older adults were not particularly prone to effects of task complexity in relation to the young college students, an intriguing result of this study suggests that the young adult non-student was particularly not prone to the complexity variable. Why this would be the case is a mystery, but a finding that requires future investigation.

In turning to the results of cross group comparisons involving the young non-student sample, these subjects provide a specific test of the disuse hypothesis of aging. The results from most every task examined in this study found that these non-student subjects had levels of performance that were somewhere in between the young-students and the elderly adults. This is important in suggesting that a variety of tasks show some effect of being in school. Since the performance levels of the non-students did not equal those of the students on the memory tests, it seems that performing those daily activities that are a part of an academic setting likely lead to increased performance levels.

General Conclusions about Language Production and Age

There are a wide variety of studies on adult developmental changes in language, but nearly all of these center on the comprehension of language. In fact, many researchers have pointed out the need for language production data to examine specific hypothetical expectations (e.g. Light, 1988). The limited number of studies that consider language production changes with age leave many unanswered questions (viz., Bromley, 1991; Emery, 1985; Obler, 1980; Ryan, Giles, Bartolucci, & Henwood, 1986). For example, Bromley (1991) has examined adult aging in written language production, but written language production allows one to sit back and reflect on what one is producing. It is only as we examine an active producer of language that we could examine any combined effects of on-line language production and memory.

Many theorists studying cognitive aging have implicated WM as a specific construct that can explain performance decrements in old adults (e.g., Salthouse, 1991a, 1991b; Stine & Wingfield, 1987; Wingfield, Lahar and Stine, 1989). Kemper has actually implicated the role of WM in the speech production of elderly adults (Kemper, 1988; Kemper & Rash, 1988; Kemper et al, 1989; Kynette & Kemper, 1986). She has drawn the conclusion that a capacity limitation in aging affects speech production. She draws this conclusion from a production task where subjects were required to imitate complex syntactic utterances. She found the older adults were much worse at this task than young adults. I would argue with Kemper in her use of the term language production. This task is in no way comparable to natural language production. First, there is no formulation stage necessary on the part of the speaker. Second, performance is dependent both on a successful production system, and on the successful memory of the original utterance. Hence, even her conclusions about an age-related decline in syntactic processing abilities should be warned- yes, it is probably, as she states, due to the increased memory demands of the long sentence constructions, hence she cannot conclude effects on syntactic *production.* The subjects are not producing anything of their own - that is she studied language use, but not language production.

Light (1988) has suggested that a useful distinction is the competence performance distinction, where performance decreases with age, but language competence remains stable. It is obvious that language comprehension is constrained by processing resources, indeed most often this causal factor (e.g. decreased WM capacity, slower processing abilities etc.) is implicated in decreased levels of performance seen with the elderly. Language performance is seen in the case of language production also. So, if these same constraints of limited resources that affect comprehension constrain the language production system, we should see decreased performance in the older adults on language production tasks. The present data does not support this possibility. It appears that language competence is indeed spared. And it is possible, as the data here suggests, that the performance of language production is spared as well. The competence performance distinction then might well be changed to a distinction of those tasks that involve memory and those that do not. I argue from the present results that speech production in natural settings may not tax the processing resources of working memory.

All in all, these results provide no evidence to suggest that capacity limitations play a significant role in the formulation of speech by healthy aging adults. Although memory limitations were evident in the elderly sampled, the smaller WM capacities (or processing resources) of the older group, even when combined with two types of tasks designed to increase the load on those impaired systems, did not present a special problem for the old. As a matter of fact, it is possible that despite all these cards stacked against them, the older adults performance in language production was superior to the two young groups tested.

The older adult is producing more informative sentences than the younger persons tested here. Does language production continue to get better across the life span ? There is no reason to believe that language production processes cannot continue to grow throughout life, certainly there is ample evidence that vocabulary tends to increase in an active healthy individual through the years (e.g. Obler & Albert, 1980, 1985). What then, would we not expect our use of that vocabulary to get better and better.

Working Memory as a Predictor of Task Performance

Daneman and Carpenter (1980) introduced the listening and reading word span tests, and found that the reading span test was related to performance abilities in reading tasks. That is, reading span is thought to assess the amount of working memory that is effective during reading. Daneman and her colleagues (Daneman & Carpenter, 1983; Daneman & Greene, 1986; Daneman & Tardif, 1987) have continued to provide evidence that suggests that a WM test in a certain domain will be more predictive of performance levels for cognitive tasks that are also in that domain. Specifically, the reading span test is predictive of several reading tasks such as integrating information between and within sentences (Daneman & Carpenter, 1983) and knowledge of the material being read (Fincher-Kiefer, Post, Greene, & Voss, 1988). Likewise, it would be expected that a test that is administered in the domain of speaking would tend to be more predictive of speech performance.

Other researchers have found mixed results when it comes to predicting task performance with working memory tests. Kemper, Kynette, Rash, O'Brien and Sprott (1989) suggested that adults with greater memory capacity produce longer utterances as measured by the number of clauses produced. Memory capacity was predictive of the number of clauses, but was not predictive for the number of words uttered (Kemper et al., 1989). The results of the present study also found no specific pattern of predictions for the number of words produced per sentence.

Daneman and Greene (1986) introduced a speaking span test that was designed specifically to tax the storage and processing functions of working memory that occur during the production of sentences. They found that speaking span was related to the fluency of word production. It was expected that this speaking span test would be the most powerful predictor in the present study for those variables involved with sentence production. The data presented here does not provide conclusive support for that hypothesis. Although the elderly's speaking spans were predictive of speech performance, unlike any of the other spans; they were the only subject group that showed any relationship between speaking span and the amount of information incorporated into their sentences.

Along with the finding that all eight memory span tests collected in this study were highly intercorrelated, the usefulness of functionally distinct tests of working memory is questioned.

The question as to whether functional working memory capacity for speaking is distinguishable from other types of complex processing such as spatial reasoning (cf. Salthouse, 1991b) reading or listening remains. It is possible that functional working memory capacity may be an entity distinct from general working memory capacity, yet functional working memory capacity may add to the general working memory capacity of the individual. I recommend the need of further work on the measurement of general working memory components. This is an open empirical question especially because the tests examined here are very similar in the use of the functional components involved with language use.

Finally, the discovery a a good test of WM capacity/function has been elusive. Cognitive aging researchers tend to use such a variety of tests that it is difficult to compare results across research studies. It is perhaps not so surprising that some people find age differences, and some do not.

The lack of support for functionally distinct WM resources have a variety of implications for the models of WM. These will be discussed next.

How do these results fit with the current models of WM ?

The fact that all the measures of memory span correlated highly with each other is particularly damaging to Monsell's (1984) notion of working memory That is, under his formulation the speaking span test should have provided a high predictability for the sentence production performance in this research. Furthermore, this speaking span task should be tapping something separate from the tests in different domains. This was not the case, in fact, all the separate tests in different domains were related equally well to each other.

It would be expected that if any portion of the WM system is involved with the production of speech, the central processor or central executive would be that portion of the working memory system involved with on-line sentence generation. Baddeley (1986) and Craik et al. (in press) have suggested that the storage systems of WM remain relatively unimpaired with age, but it is the central capacity and flexibility of the central executive that is impaired to some degree. The results of this research however, suggest that if WM is involved with sentence production, there is no specific problem as we age. There is no support for the hypothesis that control processing of the central executive system is particularly impaired with age.

One interpretation of these findings would lie in the automaticity of language capacities.

It is possible that the tasks in this experiment did not stress the central executive portion of the system because the production of speech is highly automatic. This experimental paradigm does not completely model 'real' language production. In my attempt to have some control over the production, I have given the subjects the main 'topic' of the sentence by providing two words. This means that there is not a complete 'formulation' of a sentence necessary, but only a connection of the two words presented. It is possible that under more 'real-world' language production situations, where the speaker must generate all aspects of the message, there is a greater dependency on control processes available.

It is also possible that the semantic formulation of a sentence is a modular function. That is, once the message has been generated, the system is dedicated in completing the function of selecting the appropriate method to achieve a spoken sentence. Language perception is often modeled as a modular entity, with separate modules that are encapsulated and dedicated to the processing of specific information (for example, syntactic, lexical, phonological modules). Within a modular approach, that is, assuming that language production is modular the following scenario should account for the data here: semantic activation is constant across age, suggesting that this module is spared to any effects of aging, and even if we perturb that module with an increased load, there is no differential effect with age because it is encapsulated, and dedicated and most importantly resistant to the effects of aging. Indeed, the data does suggest that even under conditions of high memory load and old age, the production of a sentence is easily accomplished.

These interpretations do not suggest that working memory is not called upon during the generation of a sentence. Sentence latencies, durations and content were all affected by increased loads on working memory for all the subjects. The working memory spans of the older adults are certainly smaller than those of their younger counterparts. Also, the performance measures in the sentence generation task were much slower for old adults in relation to young.

The results of this study are consistent with Baddeley's formulation of the working memory model. What appears from these data is that the storage component of WM is smaller with age, but there is no support for a differential decline in WM with age. This lack of support is concluded from the analysis of simple storage tasks versus working memory tasks, and from the working memory loading in the main task of the experiment. My data suggests that it is the slave storage systems which are smaller in the old, but this deficit does not play a major impact in the formulation of sentences from two words.

The other aspect of this study is the acquisition of scores from a variety of both simple and working memory span tests that are used frequently in research. It was found that despite the findings of Wingfield et al. (1988) , the old subjects were not differentially disadvantaged in the working memory tests. There is clear evidence that the capacity for performance on these tests declines with age. The present results suggest, in fact, that this decline may even begin as soon as we leave school.

Finally, results of the incidental recall of the word pairs indicate that the older subjects recalled less of these words than the young college students. Each group recalled less of the words that were presented with a simultaneous memory load of random numbers, but this concurrent task did not cause a particular difficulty for the recall by the elderly. The incidental recall of words will be examined again in the next chapter.

Specific Conclusions:

1. My data directly refute the statement "Aging affects the ongoing active decision-making aspects of processing more than it affects the relatively passive or automatic storage aspects" (Craik, Morris & Gick, in press, p.265). In fact, my data suggest that aging affects the passive storage aspects of immediate memory, but does not affect the active on-line

processing involved with speech production.

2. People of all ages speak very well, and it is likely that speech production competence is unchanged with age, and perhaps modular in function.
3. Older adults tend to devote a longer total processing time to produce a sentence, and tend to produce that sentence with a slower speech rate. These data support some aspect of slowing with increased age (e.g., Salthouse, 1991a).
4. There is a substantial age decrement in both simple storage and working memory tests.
5. The elderly produce more creative and informative sentences than younger adults. This is only found in a situation where they are not loaded with additional task demands and are given an interesting topic.
6. Young non-students from the community also tended produce more informative sentences than their college-student peers. Increasing primary task difficulty did show differential effect for the non-student young adult tested.
7. WM does not appear to test differently in the different domains of listening, reading and speaking. In fact, there is a high relationship among all the memory spans administered in this study. The testing of WM must be researched further.
8. The finding of a specific test of Working memory appears to be elusive still. It is, however, a greater possibility that there is a general working memory capacity that does not change differentially with age as we test different functional domains.
9. Young adults who are not currently pursuing academic endeavors tend to perform somewhere 'in between' the young-college students and the elderly groups in nearly every measure examined.

Finally, since one's abilities are a product of both one's biological characteristics and one's life experiences, it is likely that the effects of day-to-day experience may affect some of the variables we have examined. The performance of the YNS group consistently falls in between the levels of the YS and the Old, suggesting that there are some effects of being a student. The next chapter will address this.

CHAPTER 6.
Subject Selection in Cognitive Aging Research

Traditionally, the standard cognitive aging experiment compares a sample of elderly adults with a sample of college students (Abrahams, Hoyer, Elias & Bradigan, 1975; Hoyer, Raskind & Abrahams, 1984; Poon, Krauss & Bowles, 1984).[5] These students are most often performing this duty as a class requirement. University undergraduates tend, however, to be a very homogeneous group. This type of homogeneous control group may not be the optimal comparison sample for a typically more variable group of elderly adults recruited from the community. Furthermore, the older community dwelling adult, unlike the young, has generally been away from school for many years, and therefore does not tend to perform memory tasks on an everyday basis as much as the typical college student. This difference in the populations sampled for comparison has at least two important consequences. First, there is a common finding of increased variability in samples of older adults compared with younger controls (c.f. Schaie & Hertzog, 1985). Second, it is likely that those variables present in the day-to-day experiences of adults relate to the stability or change of cognitive function. For example, a college student who is accustomed to test-taking of all types on a routine basis may perform differently on tests of cognitive performance from an older person who has not had test taking

[5]Abrahams et al. (1975) report that 55.2% of the Gerontological research published between 1963 and 1968 employed a cross sectional research design; and that this percentage increased to 67.2% in a sample from 1969-1974. In 1984 this same group of researchers (Hoyer et al, 1984) report a yearly percentage of cross sectional reports from 1975 to 1982. These percentages ranged from 58% to 77% of all reports.

experience in recent years. This chapter will examine these consequences of methodological decisions concerning subject selection beginning with a brief discussion of the literature regarding the selection and reporting of elderly samples. Next a consideration of what variables we should control for, and how we might select appropriate samples is provided. An analysis of the data with these methodological concerns is provided. Finally, conclusions are drawn based on the examination of the non-college young adult sample in relation to the young-students and elderly adults.[6]

What the literature has to tell us about subject selection

One important source of variance among cognitive aging studies is the age range of individuals classified as aged. Depending, in part, on the subject pools available, persons of different ages may be classified as "elderly" by different researchers. This lack of consistency in how researchers define a particular age group has a potential for causing difficulties in replicability of studies or generalizability of research results (Nesselroade, 1988; Shaie, 1988). Hoyer et al (1984) surveyed the literature published in the *Journal of Gerontology (Psychological Sciences)* and found a very inconsistent representation of the age variable in terms of the age range included in a sample. The age range included in the "old" samples ranged from as young as 35 to as old as 100 years, and subjects who were classified as young ranged from 18 to 49 years of age. Schaie (1988) noted this same problem in reviewing grant proposals in behavioral aging for NIH.

This inconsistency is widespread in the field of cognitive aging (Browning & Spilich, 1981; Camp, West & Poon, 1989; Schaie, 1988). In fact, it is common to see the same

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[6]The present discussion will address only those issues pertinent to cross sectional research designs. For a discussion of longitudinal methodology, the reader is referred to Schaie (1988), Arbuckle, Gold & Andres (1986) and the first three chapters of the Handbook of the Psychology of Aging (Birren & Schaie, 1985)

researcher employing different criteria for subject selection in different studies. In taking a casual survey of the cognitive aging publications from the Brandeis University Memory Lab, I have found this typical inconsistency. Although our lab recently has set a criterion for an elderly sample as only those adults between the ages of 60-80 years old (cf., Tun, Wingfield & Stine, 1991; Lahar, 1991)[7] , in earlier research some samples of older adults ranged in age from 59-84 years (M=70.0:Wingfield, Lahar & Stine, 1989; M= 70.5: Wingfield, Stine, Lahar & Aberdeen, 1988) and others had samples ranging from 61-82 years of age (M= 70.8: Stine and Wingfield, 1988a; M=69.1, Wingfield, Aberdeen & Stine, 1991), 60-83 (M= 70.3: Stine & Wingfield,1988b), 65-80 (M=70.8; Stine & Wingfield, 1986), 65-73 (M=69.1: Wingfield, Poon, Lombardi & Lowe, 1985) , 59-81 (M=69.3: Stine & Wingfield, 1987) and 62-88 (M=71.4: Huerta, Lahar & Wingfield, 1990). Although the means for these samples fall within a very narrow range (69.1 to 71.4), the actual ages of the individual elderly subjects varied from an extreme low of 59 to a high of 88 years of age. It is these extremes that are most likely to contribute to an increased variance in the groups performance measures.

An additional problem noted when examining the literature is that many investigators fail to report information such as the health, age, education, and gender of the subjects, or how these subjects were recruited (Hoyer, Raskind, & Abrahams, 1984). Poon, Krauss and Bowles (1984) report that, at least the variables of education, health and intelligence have been systematically related to some cognitive measures. These variables can be considered "background" variables. Vocabulary, for example, is a standard index of verbal intelligence, and chronological age is a standard index of adult aging. Gender is a basic psychobiological characteristic of the individual.

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[7] Tun, Wingfield & Stine (1991) presented an elderly age range of 60-80 years old with a mean age of 69.6. The present study includes a range of 60-80 year olds with a mean age of 69.8.

Poon, Krauss and Bowles (1984) surveyed 41 papers in cognitive aging to see if these papers reported measures of intelligence, education, health and gender. Only 5 reports from that sample presented measures on all four of those subject background variables. The health status of participants was mentioned in less than half of the 41 papers (42%) and verbal intelligence was reported in 46% of the studies. Furthermore, in the cases when there was a significant age difference in these background factors, less than a third of the studies attempted to control for any possible confounding effects on the main variable of interest.

Camp et al. (1989) note that since the recruitment sites used for older subjects are more variable than those used for young, this may contribute to findings of increased variability within the older samples. Certainly, the older adults we sample from the community have a variety of occupations, living environments, daily activities and interests, all of which are likely to inflate the variability in any dependent measure. The next section will therefore discuss what variables we would want to control for in a cognitive aging test situation.

What might we want to control for in cognitive aging research?

Researchers specifically interested in cognitive aging, in the perfect world, would want to consider all the factors in the universe that may relate to cognitive performance and to the aging process. The need to examine the context and life-environment in which an individual exists has been under-represented in the research on cognitive aging (Gribbin, Schaie & Parham, 1980). Cognitive development is a complex phenomenon, and in order to more completely understand the multiplicity of factors that are involved, researchers must consider those factors that an individual brings with them to the varying cognitive tasks we create. The feasibility of accounting for the complete set of factors is impossible, yet, there have been some advances toward this utopian goal.

Perhaps the most extensive report on this topic is a study by Arbuckle, Gold and Andres

(1986) that looked at cognitive performance in the context of 12 social, personality, adjustment and lifestyle variables in a large sample of older adults. Many of the background variables they measured were important predictors of individual differences in the episodic memory tasks they employed. Education and intellectual activity were the best predictors, although age still accounted for a small but significant portion of the variance in memory measures. They support methodological critics such as Schaie in asserting "that socioeconomic, personality, and lifestyle variables modulate age differences in performance on cognitive tasks" (Arbuckle, Gold & Andres, 1986, p.61).

Gribbin, Schaie and Parham (1980) also provide a report that considers the environmental influence on cognition. They designed a Life Complexity Inventory (LCI) to assess variables present in the day-to-day experience of a large sample of 40-80 year old adults. The LCI measured a broad range of activities such as family solidarity, social status, homemaker activities and disengagement. They examined scores on this inventory for relatedness to cognitive function, and found that individuals who exhibited similar lifestyles, also displayed similar ability patterns. Furthermore, there were other sets of individuals who displayed different life-style, and hence cognitive development, patterns.

DeCarlo (1974) investigated the successful aging of a sample of elderly twins, as a function of recreational activity. Successful aging was measured in the physical health, mental health and intellectual performance domains. "Activities" were classified as sensory-motor, cognitive or affective. There was a high relationship between cognitive activity and intellectual performance and a moderate relationship between mental health and affective activity. Motor activity was not found to significantly relate to physical health. In fact, it was cognitive activity in general that had the highest relationship with successful aging (DeCarlo, 1974), supporting the notion that indeed we must account for an individuals' everyday cognitive performance.

Browning and Spilich (1981) also urge the need to understand which variables are the important sources of secondary variance which might affect subjects' performance. They mention specifically the need to examine not only the chronological age of subjects, but also the source of the subjects, matching of subjects and group heterogeneity. There is a handful of other studies that support the need to consider background and confounding variables for cognitive research. Craik, Byrd & Swanson (1987) reported that socioeconomic status and level of social and cognitive activity were related to patterns of memory loss. Schonfield (1973) reported on the relation between the number of future commitments one has to successful aging. The fact that researchers are considering various characteristics of the subjects used in cognitive aging research is a good omen. The question still remains: Are cognitive aging researchers doing this enough ?

Various situational factors may influence performance across a wide range of tasks, and indeed certain tasks are more or less likely to relate to any experience variables. It is the case that the cognitive performance measures we submit our subjects to vary tremendously, and some studies need to take special care to measure particular subject variables. For example, a study that examines the ability to perceive a visual illusion must assure that the subjects have good and normal eyesight. However, a study that examines people's ability to recall auditory speech has no need to screen for visual impairments, but a great need to screen for any hearing impairments. Likewise, a study that measures manual reaction time is much more likely to show a relation between physical health and the dependent measure than a study that measures the ability to perceive a visual illusion. The important point here is that it is dependent on what we are measuring, and the stimuli we use, in determining the appropriate factors that need control.[8]

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[8] We would expect to find a main effect of age in experiments such as those decribed, however, it is the interaction of the variable of interest and the variable of age which researchers use to demonstrate an age decrement.

What populations should we sample ?

The possibility of bias in the subject selection and recruitment methods used in cognitive aging research has been addressed in the past (The reader is referred to Nesselroade, 1988, for review of sampling issues as they relate to generalizability; Camp, West & Poon, 1989, for a review of recruitment methods; Schleser, West & Boatwright, 1986, for recruiting strategies), but there is still an under representation of these considerations in the literature. These issues are highly dependent on the goals of the research involved. There are times when we choose to select a particular (and non-representative) sample (Mook, 1989). Perhaps we are only interested in the cognitive performance of elderly left-handed native speakers of American Sign Language. Certainly we would not attempt to generalize the findings of such research to the entire aging population. On the other hand, we may wish to assure our research can be considered as representative of the entire aging population, and would therefore want to draw a broad sample of subjects from this "real-world" set in order to provide good external validity.

In cross sectional research, the researcher has the choice of what population she may choose to sample from- of either selecting a sample she wishes to generalize to, or of selecting a deliberately biased sample (Nesselroade, 1988; Schaie & Hertzog, 1985). Frequently, I choose the latter, because I study language skills, and want to examine the performance of a highly active, highly mobile, highly intelligent group of older adults. There is an unstated assumption involved in this case. The assumption is that any performance decrement appearing in this active "elite" elderly sample is surely to be found (and perhaps to an even greater extent) in the general population of aging adults. In other words, by testing these active elderly volunteers, I assume that this is a sample from the aging population that is least likely to demonstrate any deficit in cognitive performance. As reasonable as this may be, it is still an unwarranted assumption, especially without empirical research. However, when we and others draw the conclusion that a differential age difference found in this type of sample is representative of the aging adult, our colleagues have yet to take a second look.

What happens when we take a group of subjects who are a very homogeneous set ? The "everyday cognitive" performance of the aging adult is an area that may be particularly confounded by the variability of everyday activity of the subjects. However, there are some studies of cognitive aging that have considered this possible confound. Although most cross-sectional research compares college students with aging adults (Hoyer, Raskind & Abrahams, 1984), Ulatowska, Hayashi, Cannito and Fleming (1986) have provided us with a study of a select and homogeneous group of aging adults.

The sample they selected to study were a group of Roman Catholic nuns from a single order, and therefore all from a single living environment, with similar life experiences and educational background (these nuns were all engaged in teaching). This large group of 51 women were then divided into three smaller groups representing both young-old (age range 64-75) and old-old (age range 77-92) elderly groups and a third sample for comparison of middle age adults (age range 27-55). All subjects in this study were required to perform a variety of discourse tasks, in order to examine the possible deterioration of referential processes in discourse production and comprehension across the life span. These researchers conclude that there is increased linguistic variation with age, due most likely to a multiplicity of factors, including physiological and cognitive, stylistic, pragmatic and social.

Ulatowska et al. (1986) did introduce an appealing group of subjects, sampled from a selective, homogeneous, and well-educated population. They also acknowledged the costs and benefits involved with this sampling choice. Sampling a homogeneous group served to reduce threats to the internal validity of the between age group comparisons (albeit at the expense of external validity or generalizability of the obtained results). They do not fail to realize the need to delineate the multifactorial contributions to linguistic variability in elderly adults.

The effect of being a student?

Cognitive aging researchers have been warned about the limits of generalizing results from convenient samples (Nesselroade & Labouvie, 1985; Petrinovich, 1989). In the use of a cross sectional research design to examine changes in cognitive abilities across the life span, the majority of researchers choose as their young subjects a sample of college students. Less than 15 percent of the psychological aging research reports from the sample examined by Camp, West & Poon (1989) included young subjects from non-college sources. Camp and his colleagues also note a related issue; that the recruitment sites used for older subjects are more variable than those used for young, which may contribute to increased variability within the older samples. As for the young adult comparison groups, certainly college students provide an inexpensive and plentiful source. It is important then, to determine whether the performance of a college student population on everyday cognitive tasks is similar to a group of non-college young adults living in the community in terms of both variability of the sample and the similarity of the background from which subjects are drawn.

There are at least two major reasons why I postulate a need to compare students and non-students with older adults. First, the episodic memory tests that cognitive psychologists create and administer are not that dissimilar from the tests that a college student takes many times a semester. Therefore, it is likely that the daily experience with test-taking could inflate performance differences we find between young and old adults. The older adult stepping into the laboratory has rarely been involved in recent formal education, and hence has less recent practice at remembering. The younger student, however, has generally had much more recent practice with their cognitive skills (Craik & Byrd, 1982). Second, the community living environment from which we draw our samples of old adults are assuredly more variable than the living environment of the college campus. Granted, college students may represent a variety of majors, they still are living in a single environment, and most likely are engaged in similar activities in relation to each other. Yet the elderly adults we sample from the community have a variety of occupations, living environments, daily activities and interests, all of which are likely to inflate the variability in any dependent measure.

These confounds may also serve to inflate the performance differences seen in comparisons between young and old adults. One study of cognitive aging that has considered these subject selection possibilities was presented by Ratner, Schell, Crimmins, Mittelman & Baldinelli (1987). These researchers examined text recall performance in the traditional samples of older adults and college students plus a third sample of non-college young adults. Ratner et al. found that the non-college young have an average level of performance more like the elderly group than the college students on the text recall tasks they employed. So, indeed their results suggest that there is some effect of being a student, at least for text recall performance. They do not, however, report on the variability of these subject groups.

Is a recognition memory task similar to a multiple choice college exam? Is being asked to listen to and then recall a list of words very different from a student listening to lecture one day and trying to recall the information on the exam the next day? Does the routine taking of exams aid one's performance on laboratory tests of everyday cognitive performance? Is there a practice effect for college students that appears to demonstrate that the learning of rather academic and often meaningless materials presented in verbal learning studies is more difficult for the older adult (e.g. Craik & Byrd, 1982)? Does the variability of background measures relate to the variability of performance measures? All these questions must be answered within the field of cognitive aging in order to adequately produce quality research that allows us to draw appropriate conclusions about cognitive performance across the lifespan.

Introduction to Analysis

Due to the ease, inexpensiveness, and pre-established ubiquitous nature of sampling from the college sources, it is important to examine carefully the dependent measures we obtain. Accordingly, we might address this by determining whether the variability of performance of a college student sample is similar to a group of non-college young adults living in the community. The goal would be to find a young non-student sample by applying the recruitment methods we use for the older samples.

The consequences of methodological decisions concerning subject selection is examined here with specific interest in variability of dependent measures. Background measures, memory span measures and a selection of the dual-task cognitive performance measures were evaluated between subject groups for significant differences in variability. The three subject groups were those tested in the dual task speech production study: a sample of college students, a sample of young adults from the community, and a sample of elderly adults from the community. For a detailed discussion of subject recruitment, please refer back to experiment subject sample description. The subject groups' background information will be reiterated here briefly.

SUBJECTS

The data analyzed is from 18 University undergraduates with ages ranging from 18 to 22, 18 community dwelling elderly volunteers ranging in age from 60 to 80 years old and 18 community dwelling young adults ranging in age from 24 to 29 years. Both sets of community volunteers represented a wide variety of occupations and educational levels.

A criterion for participation for the young-non-student sample was that they had not been a formal student for at least the previous two years prior to the test session. No subjects in the old sample were currently engaged in formal education activity. Although none of these subjects were currently students, they had on average, participated in more years of formal education than the young-students.[9] As a reminder, the subject groups had no significant differences in vocabulary level, as measured by the vocabulary sub scale of the WAIS.[10]

PROCEDURE

The data analyzed comes from the study previously discussed. In particular, along with the background variables, the eight memory span measures and a subset of the dual task performance measured are analyzed for variability differences here. The digit recall scores were representative of one aspect of the dual task, and the propositional content of the generated sentences were selected as the data to represent the second portion of the dual task. The recall scores from the surprise free recall test were the final data set to be analyzed for variability differences among the groups.

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[9] The college student sample (mean= 13.17, SD=1.2) differed in mean level of formal years of education from both the old, $t(34)=3.72$, $p<.001$, and from the non-student group, $t(34)=5.56$, $p<.001$. There was no difference in years of education between the old(mean=15.0, SD= 1.72) and the non-student (mean= 15.28, SD=1.07) groups, $t(34)=0.58$, N.S., (see Appendix A).

[10] The mean WAIS scores were 67.44 (SD=8.61), 63.00 (SD=6.25)and 63.33 (SD=7.73)for the old, young-student, and young-non-student groups respectively.

VARIABILITY ANALYSIS

Levene's *F* ratio was applied to examine significant variance differences between the samples. Coefficients of variation were also examined to assure that any results were not confounded by a large difference in the mean values of these measures. The results were identical, so all probability levels presented are for Levene's *F*.

Appendix D presents the means, standard deviations and ranges of the memory span measures. In only four of the memory measures were any significant differences in variability detected. Furthermore, contrary to what we might expect, these differences were due to the young-students contributing a larger variance. The young-student sample had higher variance in relation to their comparison samples in the alphabet span ($p<.05$:old; $p<.05$:non-students) and the speaking span measures ($p<.01$:old; $p<.05$:non-students). The young students also demonstrated higher variability in the forward digit span ($p<.05$) and the loaded auditory span measures ($p<.05$), but only in relation to the old sample.

Means, standard deviations and ranges for the percentage of correctly recalled digits from 3 and 6 digit lists for each sample are presented in Appendix F. As we would expect, the largest variances were found in the elderly sample. In the three digit lists, this difference was significant only in comparison to the young-students ($p<.05$). There is however, a confounding ceiling effect for at least the younger group. When recalling six digit lists, however, the subjects are not at ceiling. The elderly samples' variance is statistically greater than the non-students ($p<.01$), but not the young-students.

The second dependent measure explored was the information content of the sentences generated. The amount of information produced per sentence was measured in mean number of propositions. Appendix G presents the means, standard deviations and ranges for the number of propositions produced under the three memory load conditions (no-load, low-load, and high-load). There were no mean differences in number of propositions produced under any of the three memory load conditions. However, when examining the variance of these measures, as expected, it was the older sample that tended to have the greatest variance in measures. Here again, we see the classically reported pattern of old adults providing the most variable data in all three conditions. When the sentence generation task was a single task (there was no simultaneous memory load), the elderly variance was significantly larger than the young-students ($p<.01$). No other comparison ratios were significant, however, the trend in the pattern is what we would expect.

The mean number of words recalled in the incidental free recall test are re-presented in Figure 10 (these data are originally presented in Figure 6). Figure 10 includes the standard errors of the means as a representation of the variability. It was the young-students who had the highest variability in the number of words recalled in all three memory load conditions. The elderly adults, on the other hand, exhibit the smallest variances. These differences were significant in the conditions where there was no memory load ($p<.05$) or a low memory load ($p<.05$).

Finally, recalling from earlier results, the mean numbers recalled were submitted to a 3(Age/Subject group) X 3(Memory load) ANOVA resulting in a significant effect of Group, $F(2,52)=10.46$, $p<001$ and a significant effect of Memory load, $F(2,102)=17.30$, $p<.0001$. It appears that the non-students are performing 'in between' the other two groups both in terms of the absolute performance level and the variance of incidental recall.

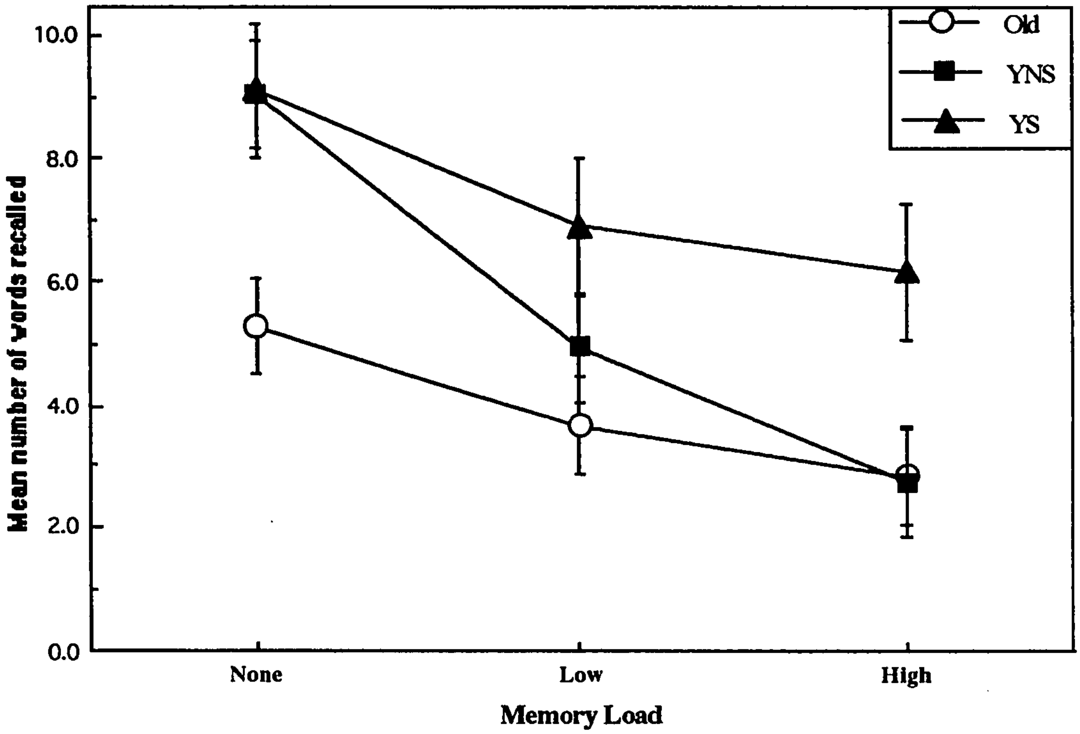

Figure 10. Incidental Word Recall with standard error bars.

Discussion of Analysis of Variability

The issue of increased variability among community based samples of young and old adults as compared to young college based samples was explored. Although cognitive aging researchers have been warned about the limits of generalizing results from convenient samples (e.g.Nesselroade & Labouvie, 1985; Petrinovich, 1989), this study found no support for the hypothesis that a young adult control group from the community provides a more appropriate control group for cross sectional research designs in terms of the variability of the measures. Although some of the measures in this study reflected the classic inflated variance of elderly adults' performance as compared to young-students, a non-college sample does not appear to be a group that alleviates such a problem.

Overall, there was no clear pattern of variance differences between groups in the measures explored here. It is yet to be determined however, whether the effect of being a student plays a role in inflating the mean differences in cognitive performance. Ratner et al. (1987) reported that non-college young adults perform more like older adults than like young college students in their tasks of prose recall. The results from incidental word recall data here hints toward the same conclusion.

There are theoretical implications of the sampling strategies we adopt in cross-sectional research designs. Measures resulting from the cognitive tasks presented to our subjects must be examined carefully. Equating groups on environmental influences may not necessarily abate a problem of variability, but may address a problem of inflated differences in between groups performance.

Conclusions on subject selection

It is the job of the cognitive aging scientist to consider the many factors that affect the quality of research produced. People are subject to a diversity of influences, and there is an increase in the attention cognitive aging researchers are paying to the characteristics of the learner or rememberer (Hultsch, Hertzog, & Dixon, 1990). Yet this work is incomplete. It has been the purpose of this chapter to remind cognitive aging specialists that lifestyle patterns are likely to relate to cognitive change and should be considered in the selection process of the subjects. It is certainly the case that aging is multifaceted, involving biological and social factors, along with psychological factors. Our theories have to allow for cumulative effects of experience and our theories should include historical antecedents of and concurrent influences on behavior (Nesselroade, 1984). Finally, we have to consider the implications of experience on all the samples we select for use in cross sectional designs.

Sampling strategies should be adopted that will allow us to achieve our goal. The research goal may be to make predictions about the real world, and in that case, a sample must be selected that is representative of that world for good external validity. In other cases, there may be an interest in replicating an effect repeatedly in a variety of settings and samples (e.g. Mook, 1989) and it is then that we should choose the samples and settings with a firm theoretical basis. In other words, we must be aware that our sampling choices involve a fine-line balance, one between selecting homogeneous samples in hopes of controlling for extraneous factors, and selecting samples from which we can generalize the results appropriately to the population in which we are interested. Hence, it is ultimately important to conceptualize the reasons for one's choice of subjects (Schaie, 1988); that is,we should adopt sampling strategies that are conceptually driven. In the end, the quality of psychological knowledge will improve with improved research practice.

As Browning and Spilich (1981, p. 184) point out: "Not only do we need to be aware of these issues to increase our understanding of age-related cognitive changes, but these issues are interesting in themselves as viewed as problems in their own right". I agree with these theorists and have suggested that the effects of current educational activity is one of many especially interesting and necessary factors to consider.

CHAPTER 7
GENERAL DISCUSSION

Review of the experimental findings

The results of the research presented in this thesis support the findings in the literature of age-related decreases in the cognitive resources necessary for optimal task performance. Furthermore, they support the fact that there is a complex interplay between processing and storage functions that is important in determining causal factors in age differences in cognitive performance (cf. Salthouse, 1991a, 1991b).

The study found that elderly adults recalled a smaller amount of digits and words in relation to college student controls. The older adult was also slower than young adults in both initiating and speaking sentences. Older adults also had inferior scores in comparison to young adults in eight memory tests. Some of these memory tests were designed to assess simple storage capacity of the immediate memory system while others were designed to tap both storage and a simultaneous processing component (i.e. working memory). Even though the elderly consistently remembered less, the performance reductions when subjects went from a simple span test to a loaded (WM) span test were not differentially greater for than elderly than for the young.

The prediction that task complexity is a fundamental factor in age decrements on cognitive tasks was upheld. Increasing task complexity in the form of semantic planning difficulty required the use of increased resources for all ages. Increasing task complexity in this way was particularly difficult for the elderly. Most interestingly, this interaction of age and complexity was the only interactive effect of age found in this study.

The fact that the older adults were not disadvantaged anymore than the young adults when placed under a memory load of digits was a rather surprising finding. This was unexpected because of the clear prediction that increased working memory load would be particularly disruptive for the older group.

Another prediction that was not supported by the results of this experiment involved the 'speaking span' test of working memory. This test was no more predictive of sentence production performance than were seven other assessments of memory storage capacity and working memory. Since the speaking span test has been claimed to be predictive of sentence production abilities, it was expected to relate to some or all of the measures of the sentences produced in this study. It was not only no more predictive of sentence production, it was highly related to all the other memory span tests. All eight of the memory span assessments were highly related, suggesting that these tests are measuring a similar component of the memory system.

A rather surprising finding was that the older adults produced the most informative sentences under some conditions. When they were allowed to devote all their attentional resources to the task, and were given an interesting topic in the form of an unrelated pair of words from which to create a sentence, they produced more information than any of the young subjects. This condition in which the older adults produced more elaborate sentences was most like a real world speech production task.

By including a second young control group of non-students, an interesting trend appeared. The level of performance of this group consistently fell somewhere between the performance of the young college students and the elderly adults. This suggests that there is some effect of being a student on the level of performance. It is possible that college students have a distinct advantage in many of the laboratory memory tests cognitive psychologists administer during empirical investigations. This advantage for those in school may serve to inflate differences in performance between young and old simply because the students are accustomed to memory demands in their daily life.

Theoretical Implications for Cognitive Aging

There are many theories that attempt to explain the deficits generally found in the cognitive performance of elderly adults. The elaboration hypothesis suggests that age deficits in cognitive performance are due to the older adult tending to encode information less deeply (e.g., Burke & Light, 1981; Craik & Rabinowitz, 1984) Similarly, it has been reported that elderly adults are less likely than young to generate extensive elaborations among words, at least when asked to commit them to memory (Howard, 1988). From these theoretical interpretations, the prediction is that incidental memory performance for the words in my study should have been improved in the no load condition for the older adults. This was the condition where the elderly produced particularly elaborate sentences, and certainly more informative than the young. The expectation then would be that memory performance would be elevated due to the elaborate sentence constructions that the elderly generated.

These extensive (or at least equal in the other conditions) elaborations by the older adult did not aid in their incidental recall of these words a few minutes later. Even with self-generated sentences that in some cases were more elaborate than the young, the older adult failed to recall as many of the words as a young adult. There is no support for Craik's elaboration hypothesis (e.g. Rabinowitz, Craik & Ackerman, 1982; Craik & Rabinowitz, 1984). My results are supported by those of Nebes and Andrews-Kulis (1976) in finding that even with self-generated elaborations, the incidental recall of the older adult is not improved.

The *processing resources* account of age-related differences in cognitive performance is certainly the predominant account today. The results of the experiment presented here suggest that processing resources are decreased with age, but this decrease does not predestine the older adult to be deficient in the production of language This conclusion is based on the assumption that conscious planning decisions necessitate the involvement of working memory. Processing resources are assumed to enable or enhance cognitive performance, and are necessary to the language production system. The older adult does have less resources available, and this deficit in comparison to the young adult was true in eight separate memory tests. The expectation then, was to see a differentially decreased (in relation to young subjects) speech production performance on the part of the elderly when they had a simultaneous memory load of digit lists. This was not the case.

Clearly the demands on WM placed by a simultaneous task do affect speech production. Every subject group showed a change in speech production with a concurrent task. Since the older group was not *differentially* disadvantaged with a concurrent task, it is likely that language production in the elderly adult remains stable. That is, the elderly have intact language production systems that are not prone to the effects of aging seen in other aspects of their cognitive performance.

If old age is associated with a decrease in processing resources, then all tasks which require resources should show a greater decrement for older than for younger adults. This was the assumption under which I have been working. However, clearly speech production requires resources, and clearly there was not a greater decrement for the older adult. It is possible then, that the older groups' decreased performance levels were due only to a smaller storage capacity, and not to a particular problem in simultaneous storage and processing of materials.

Babcock and Salthouse (1990) have suggested that it is not the degree of processing that is required in a task that serves as a major determinant of the age-related differences in working memory. They varied the amount of processing necessary in a range of tasks, and found similar age differences in performance across these tasks. Their findings suggest that age differences might remain relatively constant across wide levels of concurrent processing demands. This implies that whatever is responsible for the age decrement is relatively independent of the amount of processing required in the task (see also Tun, Wingfield & Stine, 1991).

It is possible that the methods by which processing demands were made on the subjects in this study were not adequately taxing to the processing systems involved. We may want to further explore the possibility that language performance can be perturbed more in the older adult than in the young by examining hemispheric specialization tasks concurrently with speech production tasks. If my task was not perturbing enough to the system, perhaps more difficult tasks especially designed to interfere with the left hemisphere would be (see Ballesteros, Marga, Coello, 1989; Hass & Whipple, 1985; Kinsbourne & Hicks, 1976). Hemispheric specialization tasks may allow a more in depth examination of capacity limitations and multiple resources and the complex interaction of these factors in aging.

There is clear evidence to support the fact that WM becomes less efficient with age, and that WM is important resource for many cognitive tasks. Larry Squire (1987) has stressed the importance of possible breakdowns in cognition that occur with age since these will provide valuable windows into normal cognitive process and function -as valuable as the breakdown of these processes in amnesias and aphasias.

The present study provides a strong case for the fact that any task that involves short term memory storage will decrease with age. Also supported is that ability to produce spoken language has a special place in the human processing system (e.g. Chomsky, 1965), it remains stable with age. In fact, not only does language production remain intact, these results suggests that perhaps some aspects keep getting better across the life span.

Implications for the speech production of older adults

Finding out how older adults produce speech may aid us in determining the best approaches for improving a faulty comprehension system. This also has consequences for changing the nature of our interpersonal styles. Life span changes in discourse production are elusive. We can see (hear) the behavior, but knowing and understanding differences between young and old has not been adequately researched. Although the literature has called out for data to address language production and aging, very few researchers have answered that call. This is not surprising due the difficulty of gaining any experimental control over the spoken discourse of an individual.

There are many social factors involved with language use. Boden and Bielby (1986) found that older adults manage the flow of topics within a conversation very well, but the content of the conversations focus on events in their past. This is not observed in the conversations of young (also see Obler, 1980). Perhaps recent events are less distinctive or less well-remembered for the old, and the past events are well-established memory traces such as important milestones in their lives. It is possible that focus on life events serves to reduce the retrieval demands inherent in speech production. That is, this self-focus would be a strategic method of assuring that processing resources are less taxed.

One other suggestion regarding the social factors of language use is that older adults are more interested in being interesting (Arbuckle & Harsany, 1985). It has been reported that older adults tend to recall stories in a more interesting manner rather than true to their original form. In the single-task condition in this study, where the subjects were required to create a sentence with an unrelated pair of words such as *wallet* - *stream*, the older adults produced more informative sentences than either of the two young control groups. It does appear to be true, that if given the chance, the older adult is more elaborate as they produce speech. Obler (1980) has also reported that more elaboration, complexity, and personalization occurs in the speech of 70 and 80 year olds.

Knowing that language production is generally spared in healthy aging would provide evidence that age-related performance declines are not a function of a decline of an aging language system, but of a general cognitive decline. This would allow us to direct our research focus on aspects of cognition that are showing deficits with age. Furthermore, it is just as important to know what portions of the human cognitive system remain stable with age, if only to know when things are awry. Biological and psychological theorists need to know if separate dynamic processes in age deteriorate at different rates. These findings support the idea that language, when deteriorated, is a neurological impairment specific to brain-related organic change, not chronological age (Chomsky, 1965). This provides good news for the healthy aging adult, and for the linguistic theorist, who works under the assumption that language competence is based within a biological system.

The most fascinating evidence presented here supports the possibility that language use not only remains stable, but may actually continue to 'grow' throughout the years. The fact that the sentences generated by the older adults were the most elaborate and creative of all is very exciting news. It implies the theoretical possibility of a compensatory function and the importance of accumulated experience and prolonged practice.

Rabbitt (1982) stresses the importance of practice effects - practice improves the efficiency in which people can carry out tasks. It also changes the way in which they carry out the tasks, or the way they do things. This is a realistic explanation for the improved speech of the elderly, for they have had at least 30 years of experience with language beyond that of the other subjects tested in this study. The findings of older adults producing less complex sentences (e.g. Kemper, 1988) would easily be explained with Rabbitt's interpretation. Simply put, why stress the system ?

Although I have been working under a processing resources assumption, this processing resource account alone does not account for the entire range of findings. Data such as these suggest that a mediating factors approach should be considered (Perlmutter, 1988). Perlmutter suggests that variables such as health, personality, life-style, and attitudes may predict cognitive performance to a greater degree than chronological age (1988, p. 263). This continued potential view of adulthood (Perlmutter, 1988) allows for the older adult to be slower, or to have less processing resources; but a life time of experience can aid the adult in overcoming such deficits (Perlmutter, 1988). Not only may a lifetime of experience with language provide an increased vocabulary, but perhaps even a more adaptive system with varied and richer language connections and processing capabilities.

Indeed speakers constantly produce and understand sentences they have never heard before. There is an unlimited use of language on the basis of finite experience. Science seeks uniformities, not differences, but the older adult here is being different. This is a most refreshing finding !

Implications For Models of Working Memory and Assessment of Working Memory

Despite the tremendous use of the construct of WM, there is little consensus as to what working memory really is and how it can be measured (Salthouse, 1990). As previously discussed, Salthouse separates the types of assessments of working memory into two types. The first of which is within-context assessments, which are those derived during the performance of an on-going task. The second type of assessment is out-of-context assessments, which are measurements of memory capacity acquired through specifically designed tests. It is especially the out-of-context assessments that are currently in use as task predictors.

Unfortunately, it is also these tests that lack standardization, as well as agreement on what exactly they measure.

Baddeley et al. (1985) compared two measures of WM measure to see if they were predictive of reading comprehension. One was the Daneman and Carpenter (1980) reading span, and the other was a counting span measure . In the counting span measure the subjects were required to remember the number of dots of a certain color appearing on a series of notecards. They report that both of these tests were significant predictors of reading comprehension, although the reading span was better. Baddeley suggests that there may be a specific language based WM system that is not tapped by the counting task.

It appears that whatever the memory spans administered in this study were measuring, it was predictive of the amount of accurately recalled digits. The span measures did not relate to language production, at least in terms of the timing or the amount of information conveyed. Some suggest that language production is the work of a set of subprocessors working independently (e.g. Garrett, 1984; Shattuck-Hufnagel, 1987) while other maintain that production is an interactive process (e.g. Dell, 1986; Stemberger, 1985). Regardless, the working memory model predicts that at least the speaking span test would be predictive of some measure of sentence production collected in this study (Daneman &Green, 1986). The lack of prediction in this study suggests that the speaking span test does not specifically tap a specific 'speaking working memory'.

Furthermore, if there is no general pool of resources, we would expect small or weak relationships among various measures of processing resources that tap different domains. In this study, that was not the case. My results suggest that not only are our WM tests measuring the same construct, but so are those tests designed to tap simple storage. There was no evidence from the span measures collected in this study for domain specific subprocesses of working memory. Further research on the interrelations of span measures must be done (Salthouse, 1990).

An important possibility regarding this strong relationship among the spans must be acknowledged. The present data set included eight separate memory span tests designed to tap storage and working memory processes in the domains of reading, speaking and listening. Each of those domains can be considered to fall under the general domain of language. Future research should be done on the relationship among the span tests administered in this study and a set of span tests designed to tap even more disparate domains of processing. Only then can adequate conclusions be drawn regarding the relationships of memory processing capacities of the individual.

The predominant result for the variety of tasks set out to measure WM is that the older adult performs at a lower level than a young comparison sample. What has not been established is whether it is indeed the case that the older adult shows a differential WM decrement (i.e. Wingfield et al., 1988) or whether they do not (Light & Anderson, 1985; Gick et al., 1988). The present results currently support the finding of no differential WM decrease with age. However, with the current state of working memory models, it is not that surprising that such disparate results are found. That is, the next step must be to more clearly formulate working memory models that are coincident with adequate tests of human performance.

Methodological Considerations of Subject Selection

The results of this study do show definite advantages for the young college students in relation to older adults for every task of cognitive performance. The older adult was less able to remember, or slower than these college students in each and every dependent measure examined. It is possible that a portion of the advantage that these young college students have over the old is related to the demands of their everyday life activities. In other words, the fact that these young adults are in school may play a role in inflating performance differences on various cognitive tasks. Since the non-college young adults performance levels consistently fell in between the students and the elderly, this is very likely to be the case.

It was also expected that the mean performance levels of the elderly would have a higher variance than that of the young groups. This was not found to be the case despite considerable anecdotal evidence in the literature that the old tend to produce more variable responses on our dependent measures than young.

The differences could be in the variability of the measures we collect, or in the difference of the average levels of performance between the groups. The results of this examination do not support the notion that using non-students as control will allay any great differences in the variances of the dependent measures. However, the average levels of performance in tests of memory are inflated for those young adults who are currently pursuing academic interests.

General Conclusions

Cognitive aging theorists have searched within the processing resources approach for an explanation as to why the aging adult's cognitive performance declines with age. It is a widely held assumption that there is a specific deficit in working memory with age. However, as the working memory model is currently formulated there is less and less evidence that this is the case. The current state of affairs leaves the field with a construct of working memory that is not adequately formulated for use in the field of cognitive aging. We must address the fact that our theoretical notions of working memory do not coincide with the empirical findings. I must call out for both a reformulation of the working memory models as well as an establishment of standardized tests of this construct. Only with a combination of determining just what WM is, and developing that construct, can we use it appropriately in the field of cognitive aging.

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Appendix A.

Means, standard deviations and ranges of the background measures of age, education and vocabulary for the three subject groups.

Variable	Group	Mean	Standard Deviation	Range
AGE	Old	69.8	4.83	60 - 80
	Young-Student	19.2	1.20	18 - 22
	Young-Non-Student	26.6	1.42	24 - 29
EDUCATION	Old	15.00	1.72	12 - 18
	Young-Student	13.17	1.20	12 - 16
	Young-Non-Student	15.28	1.07	13 - 17
VOCABULARY (WAIS)	Old	67.44	8.61	51 - 77
	Young-Student	63.00	6.25	55 - 76
	Young-Non-Student	63.33	7.73	52 - 76

Appendix B . Noun Pairs Presented in Experiment

RELATED	UNRELATED
ANIMAL - FOOD	BABY - DUST
APPLE - PEAR	BOTTLE - PILLOW
ARTIST - PICTURE	CHAIR - HILL
DOCTOR - PATIENT	CITY - LAKE
FARMER - FIELD	CLOCK - WINDOW
INDIAN - ARROW	DOG - OWL
MOP - SPONGE	EDITOR - BASKET
STREET - ROAD	LAWYER - TOWN
STUDENT - TEST	QUEEN - CLERK
TABLE - DOOR	RABBIT - DOLLAR
UNCLE - AUNT	TREE - BOAT
WHISKEY - GIN	WALLET - STREAM

Appendix C. Task Instructions for Dual Task Sentence Production.

INSTRUCTIONS

THIS IS A STUDY ABOUT HOW PEOPLE PRODUCE SPEECH WHILE TRYING TO REMEMBER SOMETHING ELSE. IN A MOMENT A SET OF DIGITS WILL APPEAR ON THE COMPUTER SCREEN IN FRONT OF YOU. YOUR TASK WILL BE TO REMEMBER THE DIGITS. IT IS VERY IMPORTANT THAT YOU REMEMBER THESE NUMBERS, BUT THERE IS ALSO AN ADDITIONAL TASK.

AFTER A BRIEF TIME, THE DIGITS WILL DISAPPEAR AND A PAIR OF WORDS WILL APPEAR ON THE SCREEN. AS SOON AS THE WORDS APPEAR, PLEASE PRODUCE A SENTENCE WHICH INCLUDES BOTH OF THESE WORDS AS QUICKLY AS POSSIBLE. YOU CAN MAKE UP ANY SENTENCE YOU WANT, AS LONG AS IT IS ONLY ONE SENTENCE AND IT INCLUDES BOTH OF THE WORDS THAT APPEARED ON THE SCREEN. TRY YOUR BEST TO MAKE UP A SENTENCE THAT APPROPRIATELY USES BOTH THE WORDS APPEARING ON THE SCREEN. AS SOON AS YOU HAVE FINISHED SAYING YOUR SENTENCE, PLEASE RECALL THE DIGITS THAT YOU HAD COMMITTED TO MEMORY.

SOME TIMES YOU WILL BE REQUIRED TO REMEMBER 6 DIGITS, SOMETIMES 3 AND SOMETIMES THERE WILL BE NO DIGITS AT ALL, AND YOU WILL SIMPLY MAKE UP A SENTENCE. YOU WILL BE TOLD BEFOREHAND HOW MANY DIGITS YOU WILL HAVE TO REMEMBER. IT IS VERY IMPORTANT TO TRY YOUR BEST TO REMEMBER THE DIGITS. IN FACT, OF THE TWO TASKS YOU WILL BE PERFORMING (REMEMBERING THE DIGITS AND MAKING UP A SENTENCE), IT IS MORE IMPORTANT THAT YOU REMEMBER THE DIGITS. IF YOU DO FORGET SOME, PLEASE TRY TO RECALL AS MANY AS YOU CAN REMEMBER.

IF YOU HAVE ANY QUESTIONS, PLEASE ASK THE EXPERIMENTER AT THIS TIME. WHENEVER YOU ARE READY WE WILL DO SOME FOR PRACTICE.

Appendix D.

Descriptives of the eight memory span measures for the three subject groups.

Group		Mean	Standard Deviation	Range
Forward Digit Span	Old	7.11	.83	6 - 9
	Young-Student	7.72	1.07	6 - 9
	Young-Non-Student	7.33	.97	6 - 9
Backward Digit Span	Old	5.16	1.34	3 - 7
	Young-Student	5.89	1.18	4 - 8
	Young-Non-Student	5.83	1.29	4 - 8
Alphabet Span	Old	5.37	.64	4.0 - 6.8
	Young-Student	6.29	1.10	4.7 - 9.0
	Young-Non-Student	5.68	.65	4.6 - 7.4
Simple Auditory Span	Old	4.83	.86	4 - 7
	Young-Student	6.11	1.08	5 - 8
	Young-Non-Student	6.17	.86	5 - 8
Loaded Auditory Span	Old	2.56	.75	1.5 - 4.5
	Young-Student	3.86	1.20	2.0 - 6.0
	Young-Non-Student	3.81	.88	2.0 - 5.5
Simple Reading Span	Old	4.61	.92	3 - 6
	Young-Student	5.39	1.20	4 - 9
	Young-Non-Student	5.56	.62	5 - 7
Loaded Reading Span	Old	2.94	.80	2.0 - 5.0
	Young-Student	3.44	1.04	2.0 - 6.0
	Young-Non-Student	3.58	.60	2.5 - 5.0
Loaded Speaking Span	Old	3.00	1.08	2 - 5
	Young-Student	3.89	.69	2 - 6
	Young-Non-Student	3.28	.67	2 - 5

APPENDIX E.

FACTOR LOADINGS FOR EACH OF THE EIGHT MEMORY SPAN VARIABLES IN THE COMPONENT FACTOR ANALYSIS.

	eigen value
FACTOR 1:	4.426
	(Carmines Theta= 0.8846)
FACTOR 2:	0.901
FACTOR 3:	0.764

	Factor 1 Loadings
Forward Digit	0.597
Backward Digit	0.534
Alphabet	0.730
Speaking	0.808
Loaded Listening	0.803
Loaded Reading	0.766
Simple Listening	0.829
Simple Reading	0.824

Appendix F.

Means, standard deviations and ranges of the percent of digit's correctly recalled by the three subject groups. These recall measures represent the digit lists to be remembered while subjects were simultaneously generating sentences.

Digit Recall Task	Group	Mean	Standard Deviation	Range
Percent Recall of 3 digits	Old	88.43	12.42	54.2 - 100
	Young-Student	93.52	6.27	79.2 - 100
	Young-Non-Student	92.59	10.26	62.5 - 100
Percent Recall of 6 digits	Old	65.51	17.94	33.3 - 93.8
	Young-Student	79.17	13.00	54.2 - 97.9
	Young-Non-Student	85.65	8.21	64.6 - 97.9

Appendix G.

Means, standard deviations and ranges of the number of propositions produced under each memory load condition for the three subject groups.

Sentence Production	Group	Mean	Standard Deviation	Range
propositions produced (no load)	Old	3.45	1.48	2.0 - 7.1
	Young-Student	2.92	0.77	2.0 - 4.6
	Young-Non-Student	3.20	0.91	1.6 - 5.1
propositions produced (low load)	Old	2.85	0.94	1.7 - 5.5
	Young-Student	2.42	0.75	1.5 - 4.6
	Young-Non-Student	2.69	0.54	1.8 - 3.7
propositions produced (high load)	Old	2.69	0.77	1.8 - 4.2
	Young-Student	2.45	0.51	1.8 - 3.5
	Young-Non-Student	2.45	0.49	1.8 - 3.7