EFFECTS OF PRESENTATION MODALITY ON LANGUAGE PROCESSING IN

YOUNG AND OLDER ADULTS

by

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SIGNED: Esther Sung Kim
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DEDICATION

This work is dedicated to the memory of my mother, Sung-Ok Kim, who taught me that “I can do everything through Him who gives me strength” Philippians 4:13.
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ABSTRACT

The segment of the population that is 65 years and older is undergoing rapid growth. With this growth, there is an increased need for speech-language pathologists (SLPs) to treat cognitive-communicative disorders, most of which are age-related disorders secondary to neurologic disease. To do this effectively, SLPs require an understanding of how healthy aging affects cognition, memory and sensory processing. Although the interactions between sensory and cognitive processing are increasingly being investigated, little attention has been paid to the relationship between modality of information presentation and language comprehension in aging. Language comprehension is affected by component processes such as memory span and processing abilities, but to date there has been no systematic investigation of the effect of presentation modality on the processing of linguistic information across a number of tasks ranging in complexity.

The primary purpose of this study was to investigate the effects of presentation modality on language processing. The secondary purposes of the study were to determine whether age affected performance on language processing measures, and whether adults can accurately predict if their performance was better in either the auditory or visual presentation condition. The effects of presentation modality were evaluated on four dependent measures: a digit span task, a word span task, a complex span task and a procedural instruction processing task. The participants were 37 older adults and 41 younger adults, matched for years of education and estimated verbal IQ.
Three notable findings emerged from the study. First, both young and older adults recalled more information when it was presented in the auditory modality, regardless of the task. Second, age effects were present on all measures. Third, individuals were generally inaccurate in predicting which modality would result in better processing. Implications for the evaluation and treatment of older adults are discussed.
INTRODUCTION

The fastest growing segment of the population is that of individuals 65 years of age and older. The percentage of Americans over the age of 65 increased from 4% in 1900 to 12% in 2000 (Whitbourne, 2001) and this number is projected to rise to 21%, or roughly 86 million people by the year 2050 (U.S. Bureau of the Census, 2004). With this rapid growth in the elderly population comes an increased need for speech-language pathology (SLP) services to treat cognitive-communicative disorders, most of which are age-related and secondary to neurologic disease.

In order for SLPs to effectively treat elders, knowledge of how healthy aging affects cognition, memory and sensory processing is required. Not only do changes in these functions directly impact communication, investigators have also reported that sensory functioning can interact with higher order cognitive abilities to negatively impact language processing (Salthouse, Hancock, Meinz & Hambrick, 1996; Schneider, Daneman & Pichora-Fuller, 2002). Despite the fact that studies of these interactions are increasing, little attention has been paid to the relationship between modality of information presentation and language comprehension in aging. Specifically, the question of whether language comprehension in older adults is better in one modality than the other remains unanswered. As many individuals often preferentially rely on one modality over another, to compensate for vision or hearing difficulties, it is important to understand the basic effects of presentation modality on language comprehension, in individuals without sensory impairment.
To address this question, it is essential to recognize that language comprehension depends on a number of component processes. Figure 1 presents a framework (adapted from Kwong See & Ryan, 1996) outlining the cognitive operations involved in language comprehension. Further, an understanding of how these component processes are affected by aging and presentation modality is also required.
Figure 1

Framework outlining the cognitive operations involved in discourse processing (adapted from Kwong See & Ryan, 1996)
It is apparent from examining Figure 1 that working memory, and storage processes within working memory, are important to language comprehension. In a meta-analysis conducted by Daneman and Merikle (1996), the relationship between language comprehension and working memory capacity was investigated. They reported that language comprehension tests correlated with measures of storage, as well as measures of storage and processing. As these are measures of primary and working memory, respectively, it is necessary to delineate how these constructs are affected by aging.

**Age Related Changes in Primary and Working Memory**

The term *primary memory* (PM) was suggested by Waugh and Norman (1965) to refer to the limited capacity store of information that could be held at any one time. The concept of PM is distinguished from that of *working memory* (WM), introduced by Baddeley and Hitch (1974), and constitutes a multi-component system that combines retention and processing of information. Craik and Rabinowitz (1984) suggest that PM and WM are actually part of the same system, and tasks designed to measure them lie on a passive-active continuum of ‘short-term memory’. An example of a passive task is one that requires only the storage of information, such as the recall of a string of digits; an active task requires both storage and manipulation of information (Craik, 2000). Another way that measures of PM and WM have been distinguished are by the terms ‘simple span’ and ‘complex span’ (LaPointe & Engle, 1990; McCabe & Hartman, 2003). Simple span tasks refer to tasks such as digit span or word span that involve only a storage component, and are equivalent to the passive tasks in Craik’s dichotomy. Although there is general agreement that age effects on simple span measures are modest or nonexistent
(Bäckman, Small & Wahlin, 2001; Craik, 2000; Kausler, 1994), some investigators have reported significant age-related deficits in PM based on performance on digit span tasks (Salthouse & Babcock, 1991; Wechsler, 1987).

On word span tasks, age effects have consistently been reported (Kausler & Puckett, 1979; Salthouse & Babcock, 1991; Wingfield, Stine, Lahar & Aberdeen 1988). Whereas items in the digit span task are drawn from a limited set (9 digits), it is possible that more extensive processing is required when the to-be-remembered items come from a larger pool as is the case on word span tasks.

Complex span tasks refer to tasks requiring active processing in addition to storage of information, and are therefore considered to be measures of WM. There is much greater consensus for an age effect on complex span tasks. One widely used measure of complex span is the sentence span task, introduced by Daneman and Carpenter (1980). In this task, participants are required to either read or listen to a series of sentences and recall the last word in each. Both passive storage and active processing of words are required because subjects have to make a judgment about the sentence. Age differences on this task have been widely reported (for reviews see Bopp & Verhaeghen, 2005, Carpenter, Miyake & Just, 1994 and Verhaeghen & Salthouse, 1997). In fact, age effects on a variety of complex span measures, including computational span (Salthouse & Babcock, 1991), operation span (Turner & Engle, 1989) and text span (Norman, Kemper, Kynette, Cheung & Anagnopoulos, 1991), have appeared in the literature. A consideration of primary and working memory capacities is essential when presenting information to older individuals. However, it is also necessary to understand how
modality of information input affects language comprehension, and whether presentation modality interacts with primary and working memory capacities.

**Modality Effects on Primary and Working Memory**

Most investigations of modality effects on primary memory have come from studies on iconic and echoic memory. Investigators compared the effects of visual versus auditory presentation on a variety of stimuli, including letters (Manning & Greenhut-Wertz, 1990), digits (Taub, 1972; Taub & Kline, 1976) and word lists (Arenberg, 1976). In a review of the effects of presentation modality on short-term verbal memory, Penney (1975) concluded that there is a modality effect in that auditory presentation results in superior recall of items near the ends of lists (recency part of the serial position curve). However, exceptions to this phenomenon have also been observed. Botwinick and Storandt (1974) found a slight superiority for visual presentation of letters relative to auditory presentation, for both older and younger adults. Arenberg (1976) reported an advantage for visual presentation over auditory presentation for both older and younger adults for items in the early serial positions of his lists, and Taub and Kline (1976) reported that visual presentation of digits resulted in better recall than auditory presentation when lists were presented in a simultaneous visual condition (all digits presented at once, for a duration equivalent to 1 second per digit).

Unlike investigations of modality effects on primary memory, studies of modality effects on working memory, particularly as a function of age, are scarce. However, in studies with young adults, performance on measures of WM appears to be better when the information is presented aurally as opposed to visually. In a recent study, Goolkasian
and Foos (2002) examined effects of presentation format on working memory in college undergraduate students. They combined a sentence verification task involving mathematical operations (e.g. “Is \((2/1) + 1 = 2?\)”) with a span task involving words presented in picture, printed word or spoken word formats. Results indicated that participants recalled more words when they were presented in spoken format over picture and printed word formats. Further, the spoken words resulted in less errors and faster reaction times during the processing task. The authors state that although generalization to other kinds of material may be limited, the manner in which information is presented has an influence on working memory in young adults. In their seminal paper, Daneman and Carpenter (1980) compared performance of 21 college undergraduates on the listening and reading versions of their sentence span task. Differences were slight, but mean span scores were higher for the listening span task (mean = 2.95, SD = .72) than the reading span task (mean = 2.38, SD = .70). Although a study directly comparing the performance of older adults on the reading versus listening versions of the sentence span task does not exist, comparisons are available by examining evidence from a meta-analysis conducted by Bopp and Verhaeghen (2005). Using mean values weighted for sample size, they reported that the age difference in mean span sizes between older and younger adults on the listening span task (1.27, from 12 studies) was larger than the reading span task (.63, from 28 studies). Examination of mean span scores revealed that younger adults seemed to have lower span scores for the reading version of the sentence span task compared to the listening version, whereas older adults have higher scores for reading compared to listening. Of course, these values must be interpreted with caution as
they were not taken from the same studies with the same participants; nonetheless they provide evidence for differential effects of modality on working memory performance in young and older adults. Given that modality of presentation can interact with working memory performance, by extension, language comprehension may also be affected by modality of information presentation. A consideration of this statement requires further exploration of the relationship between working memory and language comprehension.

**Contributions of Working Memory to Language Comprehension**

The comprehension of spoken or written language involves a number of simultaneous component processes (Figure 1). Besides speech/letter recognition functions, the individual must form representations of syntactic, semantic and pragmatic information, and hold these representations in consciousness while continuously integrating new information. Working memory, with its dual capacities for processing and storage is thought to be the avenue by which comprehension of language takes place. Although much evidence supports the relationship between working memory capacity and language comprehension, the data have been correlational in nature. In Daneman and Merikle’s (1996) meta-analysis, correlations between WM measures and comprehension measures were .41 and .52, for general (standardized) comprehension tests and specific (non-standardized) comprehension tests, respectively. Further, their analysis revealed that the predictive power of WM measures on language comprehension was not specific to the language processes involved in the WM task (i.e. sentence span tasks). This correlation was also found when the task used mathematical processes as the predictive
WM measure, such as in the operation span (Turner & Engle, 1989) or computation span (Salthouse & Babcock, 1991) tasks.

More recently, investigators have used structural equation modeling to determine the effects of WM capacity on language comprehension. Van der Linden et al. (1999) distinguished the effects of WM capacity limitations from those due to reductions in processing speed or a breakdown of inhibitory processes, by examining performance on a wide range of language tasks. Young and older adults were given a battery of tests designed to measure processing speed, WM capacity, ability to inhibit distracting thoughts, understanding of texts, and ability to recall words, sentences and stories. The analyses revealed that the relationship between age and performance on language comprehension tasks was indirect and mediated through age-related reductions in speed, resistance to interference, and WM. Further, the contributions of speed and resistance to interference were indirect and mediated by WM capacity, hence WM capacity was the main factor accounting for age differences in language comprehension tasks. Similarly, Dede, Caplan, Kemtes and Waters (2004) used a structural modeling approach to investigate effects of age and verbal working memory on three types of language measures: online syntactic processing, sentence comprehension, and text comprehension. Again, the best fit model for sentence and text comprehension revealed an indirect effect of age mediated by verbal working memory.

The hypothesis that limitations in WM capacity account for age-related language comprehension deficits is one that has a growing base of evidence (Brèbion, 2003; Caplan & Waters 1999; Norman, Kemper & Kynette, 1992; Van der Linden et al., 1999).
However, there are a number of other factors that contribute to comprehension of language. Again, referring back to Figure 1, factors such as vocabulary, episodic and semantic memory all play a role. As these are factors that are affected by age, changes in these cognitive abilities can also affect an older adult’s ability to comprehend language (Kemper & Mitzner, 2001).

**Age Related Changes in Language Comprehension**

Studies of spoken and text-based discourse have led to attempts to model the cognitive abilities required to comprehend information. In fact, discourse comprehension provides a useful means to investigate theories of cognitive aging and the mechanisms that account for age-related differences. The overwhelming conclusion from studies of discourse comprehension is that older adults recall less information than younger adults, and these differences persist despite manipulations of type of information (i.e. narrative versus informational) (Harris, Rogers & Qualls, 1998; Hartley, 1986; Luszcz, 1993), length of text (Hartley, 1993), propositional density (Stine & Wingfield, 1990), and types of measures used to assess comprehension (Jackson & Kemper, 1993; Riggs, Wingfield & Tun, 1993). Because these manipulations of discourse variables resulted in age effects, researchers hypothesized that investigating individual differences would shed light on factors accounting for age differences in language comprehension (Hartley, 1988). Indeed, differential performance on discourse comprehension tasks, based on individual differences in verbal knowledge (Meyer & Rice, 1983; Hartley, 1988), thematic (script) knowledge (Hultsch & Dixon, 1983) and episodic memory (Kluger, Ferris, Golomb, Mittelman & Reisberg, 1999; Rubin et al., 1988) have all been reported. Although
discourse variables and individual variables have an effect on comprehension, an important factor that likely influenced the results of these studies is presentation modality.

**Modality Effects on Language Comprehension Tasks**

Few investigators have directly compared modalities of presentation on comprehension of spoken and written discourse. Taub and Kline (1976; 1978) found that both older and younger adults recalled more information from prose passages after visual presentation than auditory presentation. They attributed this to the fact that with visual presentation, the passage was available for review, and indeed, found that when the opportunity to review was taken away, there were no differences between the two modalities of presentation. Corgiat, Templer and Newell (1989) also found that both younger and older adults recalled more information after reading long prose passages than after hearing them. However, they did not include a condition where the written material was unavailable for review. Dixon, Simon, Nowak and Hultsch (1982) examined age and modality differences on immediate and delayed recall of information from news articles. They reported that at immediate recall, young and middle-aged participants recalled more information in the reading versus hearing conditions, whereas the older participants did not show a modality effect. However, when recall of information was tested one week later, the older group recalled significantly more information from the auditory over the visual condition, whereas no differences existed for the young and middle-aged groups. Dixon and colleagues suggested that older adults were less likely to
take advantage of the opportunity to review the material during reading, a fact that accounted for the lack of a modality effect in the immediate condition.

**Purpose of Current Study**

The notion that language comprehension is affected by memory span and processing capacities is supported by the studies reviewed. However, task variables such as the complexity of information to be processed and modality of information presentation also affect language comprehension. Although some information on modality effects is available from studies of discourse comprehension, to date there has been no systematic investigation of the effect of presentation modality on the processing of linguistic information across a number of tasks ranging in complexity. Moreover, a study examining effects of presentation modality on language processing tasks, while controlling for episodic memory retrieval, thematic/content knowledge, and age has not been done. Not only would such a study add to our understanding of language comprehension in normal adults, it would provide information useful to clinicians.

SLPs frequently are required to design and implement treatment programs for older adults with cognitive-communicative disorders. To effectively treat patients, it is crucial that SLPs understand how healthy older individuals process information by the auditory and visual modalities. SLPs and other health professionals generally present information to patients and their families aurally. However, there is no evidence to suggest that individuals process information best in this modality. There may be individuals who comprehend information better when it is presented in the visual
modality. Further, it is unknown whether adults can predict which is their preferred modality for processing information, and whether they are accurate in their predictions.

The primary purpose of this study was to investigate the effects of presentation modality on language processing. The secondary purposes of the study were to determine whether age affected performance on language processing measures, and whether adults could accurately predict if their performance would be better in either the auditory or visual presentation condition. The effects of presentation modality were evaluated on four dependent measures: digit span (Wechsler, 1987), word span (after Wingfield et al., 1988) an assessment of complex memory span (Daneman & Carpenter, 1980) and a procedural instruction processing task (organizing pills into a pill container). Participants were administered each of these measures aurally and visually.

The research questions and hypotheses were:

1. Does modality of presentation (auditory, visual) of linguistic information affect performance on digit span, word span, complex span and processing of procedural instructions in young and older adults?

*Hypotheses:* Both young and older adults will perform better when information is presented aurally regardless of task.

*Rationale for hypotheses:* Although results are mixed on performance on WM and discourse comprehension measures, aural presentation has been shown to be superior for measures of primary memory span. As span capacity is a component of language processing, it is predicted that individuals will do better when instructions are presented in the auditory modality.
2. Will older adults perform significantly poorer on the procedural and memory
tasks than younger adults?

_Hypotheses:_ Older adults will perform significantly poorer than younger adults on
all measures.

_Rationale for hypotheses:_ Age effects on measures of primary memory, working
memory and language processing have been widely reported in the literature.

3. Will adults be accurate in their predictions about the effect of presentation
modality on performance?

_Hypotheses:_ Adults will be accurate in their predictions about the effect of
presentation modality on their performance.

_Rationale for hypotheses:_ Evidence from the education literature suggests that
adults perform better when instruction matches their modality of preference
(Boulmetis & Sabula, 1996; McKeachie, 1999).
METHODS

Participants

Study participants were 41 young adults (M = 22.5 years, Range = 18-29 years) and 37 older adults (M = 72.1 years, Range = 60-91 years). Young adults were recruited from the community and from the University of Arizona, and consisted of 25 females and 16 males, with a mean of 15.2 years of education (Range = 12-22 years). Fifty-four percent (22) of the young adult sample was Caucasian, and the remaining 46% comprised individuals of Hispanic (24%), African-American (7%), Asian-American (5%), American Indian (3%) and mixed (7%) origin. Older adults were recruited from the community and consisted of 24 females and 13 males, with a mean of 15.7 years of education (Range = 9-22 years). Seventy-three percent (27) of the older adult sample was Caucasian, and the remaining 27% comprised individuals of Hispanic (11%), African-American (11%) and Asian-American (5%) origin. All participants were literate, spoke English as a primary language, had no history of drug/alcohol dependency, psychiatric disorder or mental illness, neurological disorder, brain trauma, or major cardiovascular disease, as determined by self-report. In addition, all participants reported they did not have dyslexia or difficulties with reading. Informed consent was obtained from all individuals. Demographic information for the two groups of subjects is presented in Table 1.
Table 1
Demographic characteristics of study participants

<table>
<thead>
<tr>
<th></th>
<th>Young Adults</th>
<th>Older Adults</th>
</tr>
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<tbody>
<tr>
<td><strong>Number</strong></td>
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<td></td>
</tr>
<tr>
<td>males</td>
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</tr>
<tr>
<td>females</td>
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<td>24</td>
</tr>
<tr>
<td><strong>Ethnicity</strong></td>
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<td>Caucasian</td>
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<td>4</td>
</tr>
<tr>
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<td>2</td>
</tr>
<tr>
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<tr>
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</tr>
<tr>
<td><strong>Age</strong></td>
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</tr>
<tr>
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</tr>
<tr>
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</tr>
<tr>
<td>Range</td>
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<td>60-91</td>
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<tr>
<td><strong>Education</strong></td>
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<tr>
<td>Mean</td>
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<tr>
<td>SD</td>
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<td>9-22</td>
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<tr>
<td><strong>MMSE</strong></td>
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</tr>
<tr>
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<td>28.7</td>
</tr>
<tr>
<td>SD</td>
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<td>1.3</td>
</tr>
<tr>
<td>Range</td>
<td>29-30</td>
<td>27-30</td>
</tr>
</tbody>
</table>
Screening of Sensory Function

To rule out sensory deficits, all participants were screened for functional vision and hearing. Participants were administered the Visual Perception and Literacy, and Visual Agnosia screening tasks from the *Arizona Battery for Communication Disorders of Dementia* (Bayles & Tomoeda, 1991). The Visual Perception and Literacy screening task requires the participant to read aloud sentences printed in 18pt. font. All written instructions on the experimental tasks were written in at least this size font or larger. The Visual Agnosia screening task requires the participant to correctly identify three black and white line drawings of common objects (*cup, hammer, fork*).

Hearing function was screened by administering a speech recognition measure, the Boothroyd Isophonemic Word Lists (Boothroyd, 1984). Each list comprises 10 CVC words drawn from the same pool of 30 phonemes and is scored phonemically, resulting in a speech recognition score based on 30 items (Markides, 1997). Individuals with normal hearing typically repeat the words with at least 90% accuracy (27/30 phonemes correct). Participants were administered one list in an auditory-only condition such that the examiner’s face was not visible to the participant. Those who did not score above 27/30 were administered a second list. Individuals who scored below 27/30 on the second list were excluded from participation in the study. (See Appendix A for the word lists used). All tasks were administered in a quiet room either in the participant’s home, at a community senior center, or in the Department of Speech, Language, and Hearing Sciences at the University of Arizona.
Assessment of Cognitive Function

In order to assess general cognitive functioning, the Mini-Mental State Examination (MMSE; Folstein, Folstein & McHugh, 1975) was administered. The MMSE is a widely used mental status test comprising 11 items designed to assess orientation to time and place, immediate and delayed recall, attention and calculation, language and visuo-spatial constructional ability. The maximum score on the MMSE is 30, and scores of 26 or less are indicative of functional impairment (Lemsky, Smith, Malec & Ivnik, 1996). All participants scored between 27-30 points on the MMSE, with an average of 28.7 for the older group and 29.8 for the younger group (see Table 1).

In order to estimate verbal IQ, a regression equation using demographic variables was also calculated (Barona, Reynolds & Chastain, 1984). The Barona et al. regression equation uses age, gender, ethnicity, education, occupation and residence (urban-rural) to estimate verbal IQ as follows:

\[
\text{Estimated } VIQ = 54.23 + .49(\text{age}) + 1.92(\text{gender}) + 4.24(\text{ethnicity}) + 5.25(\text{education}) + 1.89(\text{occupation}) + 1.24(U-R \text{ residence})
\]

Codes for the variables used in this equation can be found in the original paper. The standard error of estimate for this demographic regression equation is 11.79 (Barona et al., 1984). Estimated verbal IQ values and between group differences in demographic variables are reported in Table 2.
Table 2
Between group differences on demographic variables

<table>
<thead>
<tr>
<th>Variable</th>
<th>Young</th>
<th>Old</th>
<th>Degrees of Freedom</th>
<th>F</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean</td>
<td>22.5</td>
<td>72.1</td>
<td>1, 77</td>
<td>1370.83</td>
<td>.00</td>
</tr>
<tr>
<td>SD</td>
<td>2.9</td>
<td>8.0</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Education</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean</td>
<td>15.2</td>
<td>15.7</td>
<td>1, 77</td>
<td>.50</td>
<td>.48</td>
</tr>
<tr>
<td>SD</td>
<td>2.7</td>
<td>3.0</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MMSE</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean</td>
<td>29.9</td>
<td>28.7</td>
<td>1, 77</td>
<td>31.60</td>
<td>.00</td>
</tr>
<tr>
<td>SD</td>
<td>.3</td>
<td>1.3</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Est VIQ</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean</td>
<td>106.5</td>
<td>107.0</td>
<td>1, 77</td>
<td>.09</td>
<td>.76</td>
</tr>
<tr>
<td>SD</td>
<td>6.0</td>
<td>6.9</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Assessment of Simple Memory Span: Forward Digit Span

Stimuli. The forward digit span test from the Wechsler Memory Scale Revised (WMS-R; Wechsler, 1987) was used as a measure of primary memory span. An alternate form of the digit span test was constructed using the digits from the backward digit span test of the WMS-R.

Administration. The digit span test was administered in both auditory and visual presentation conditions. Order of presentation (auditory, visual) was counterbalanced between participants, and the version of the digit span test presented was also counterbalanced between conditions. In the auditory condition, participants heard progressively longer strings of random digits and recalled them immediately in the order given. The examiner presented the digits without intonation at a rate of one digit per second. In the visual condition, digits were printed on 2 x 3.5” index cards, and presented
at a rate of one card per second. Blank cards were inserted in between trials. Participants were instructed to recall the preceding digits in the order presented whenever a blank card was seen. Two trials at each level (two to nine digits) were presented.

Scoring. Digit span was calculated as the maximum length at which at least one of the two lists was completely recalled in the correct order. Testing was discontinued when both trials of a particular length were missed.

Assessment of Simple Memory Span: Word Span

Stimuli. A word span test was given as an additional measure of primary memory span. Lists of words ranging from two to eight items were constructed using single syllable, high frequency (Kucera & Francis [1967] frequency of 60+) unrelated nouns. Two alternate versions were constructed. (See Appendix B for list of words used.)

Administration. As with the digit span test, the word span test was also presented in an auditory and a visual condition. The order of presentation (auditory, visual) as well as the version administered (A or B) was counterbalanced between participants. In the auditory version, the examiner presented the words without intonation at a rate of one word/second. Participants were instructed to recall the words in the order presented. In the visual condition, words were typed in 22 pt. Helvetica font on 8.5 x 11” sheets of paper. The sheets were loaded in clear sheet protectors in a three-ring binder. The examiner flipped each page such that words were displayed at a rate of one word/second. Blank sheets of paper were inserted in between trials, and participants were instructed to recall the preceding words in the order presented whenever a blank sheet appeared. Two trials at each level (two to eight words) were presented.
Scoring. Word span was calculated as the maximum length at which at least one of the two lists was correctly recalled. As with the digit span, testing was discontinued when both lists at a particular length were missed.

Assessment of Complex Memory Span: Sentence Span

Stimuli. Complex memory span was assessed using the listening span (auditory presentation) and reading span (visual presentation) sentences from Daneman and Carpenter’s (1980) sentence span task. Sentences were nine to sixteen words in length, with different sentence-final words. Sentences were taken from general knowledge quiz books and were structured such that half were true and half were false. Sentences were typed in 18 pt. Helvetica font on 8.5 x 11” sheets of paper in landscape orientation. The sheets of paper were inserted into clear sheet protectors and loaded into a three-ring binder.

Administration. In the auditory condition, participants listened to sets of sentences while answering true or false after each sentence in the set. The examiner read each sentence to the participant at a rate of five to seven seconds/sentence. In the visual condition, participants silently read sentences and then answered true or false aloud. The examiner then flipped to the next sentence in the set. The end of each set was signaled by the examiner saying “okay” in the auditory condition, or by a blank sheet of paper in the visual condition. Participants were then required to recall the last word of each sentence in the set. Set lengths ranged from two to six sentences, and three trials at each length were administered. Testing was discontinued when the participant failed all three trials of a given set length. Practice trials at the two-sentence level were administered prior to
starting the task. Although the time taken by participants to read the sentences in the visual condition was not equated precisely with the time taken to present the sentence in the auditory condition, if the participant did not respond true or false within ten seconds, the examiner flipped to the next sentence.

**Scoring.** Participants were not scored on whether they answered the true/false portion of the task correctly. This requirement was added to ensure that participants were processing the full sentences for meaning, rather than simply listening to/reading the final word. Sentence spans were calculated as the set-size level at which the participant recalled all of the sentence-final words for at least two out of the three sets at that set-size level. Credit was given for remembering all of the final words, irrespective of order. In addition, a further half credit was awarded to the participant’s recorded span if he/she recalled all of the words in one of the three sentence sets presented at the next higher set-size level. These scoring guidelines, taken from the original Daneman and Carpenter (1980) paper have continued to be the standard method used to score sentence span tasks (Conway et al., 2005).

In addition, the number of intrusion and omission errors made by the participants in recalling the last words on this task was tallied. Intrusion errors were of two types: recalled words from the sentences studied that were not in the final position, and recalled words that were responses to previous items. Omission errors comprised items for which participants did not produce a response.
Assessment of Language Processing: Procedural Instruction Task

The procedural instruction task was designed to assess ability to process language controlling for effects of differences in vocabulary, script knowledge and episodic memory. The task was to sort pills into a week-long pill container according to directions that were either heard or read. The directions became progressively more complex, incorporating additional elements and increasing in length.

Stimuli. Stimuli consisted of three colors (white, red, blue) of round pills of identical size, and two clear plastic pill containers divided into seven compartments denoting days of the week. Directive statements for sorting pills into the containers were constructed and organized into three levels of difficulty. In Level 1, two components were incorporated into the directions: number of pills to be taken, and day of the week (e.g. “Take two pills on Wednesday”). Only one color of pill and one pill container was presented for the trials in Level 1 (see Figure 2.1). In Level 2, a second pill container was added, such that the two containers represented morning and afternoon. Three components were incorporated into the directions in Level 2: number of pills to be taken, day of the week, and time of day (morning/afternoon). In Level 3, the remaining two colors of pills were added, hence there were four components incorporated into the directions: number of pills to be taken, day of the week, time of day (morning/afternoon), and color of pill. Figures 2.1-2.3 illustrate the arrangement of the pillbox for each of Levels 1-3.
Figure 2.1
Pill box arrangement for the Level 1B instruction “Take 1 pill on Monday and 2 on Thursday”
Figure 2.2
Pill box arrangement for the Level 2B instruction “Take 2 pills on Sunday morning and 1 on Wednesday afternoon”
Figure 2.3
Pill box arrangement for the Level 3C instruction “Take 2 red pills on Monday morning, 2 white on Saturday afternoon and 1 blue on Wednesday morning”
Within each level, the number of actions required to complete the instruction increased from one to four (labeled “A” through “D”). For instance in the Level 2B instruction “Take 3 pills on Saturday afternoon and 1 on Monday morning,” two actions were required to complete the instruction, with each action incorporating three components (number of pills, day of week, morning/afternoon).

Instructions were constructed by randomly choosing items from the following ranges for each element: number of pills (1, 2 or 3), days of the week (Sunday through Saturday), time of day (morning or afternoon) and color (white, red, or blue). Although certain selections may have been repeated within an instruction (e.g. Friday morning and Friday afternoon) no instruction required more than one set of pills to be placed in any compartment of the container. Table 3 provides sample instructions illustrating the organization of levels. The number in parentheses following each instruction represents the number of components to be remembered.
Table 3
Sample instructions for procedural instruction processing task

<table>
<thead>
<tr>
<th>Level</th>
<th>1</th>
<th>2</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Take 1 pill on Saturday. (2)</td>
<td>Take 2 pills on Thursday afternoon. (3)</td>
<td>Take 1 red pill on Saturday morning. (4)</td>
</tr>
<tr>
<td>B</td>
<td>Take 1 pill on Wednesday and 3 on Monday. (4)</td>
<td>Take 3 pills on Saturday afternoon and 1 on Monday morning. (6)</td>
<td>Take 2 white pills on Tuesday afternoon and 1 white on Thursday afternoon. (8)</td>
</tr>
<tr>
<td>C</td>
<td>Take 2 pills on Thursday, 1 on Sunday and 1 on Friday. (6)</td>
<td>Take 1 pill on Wednesday morning, 2 on Tuesday morning and 1 on Friday afternoon. (9)</td>
<td>Take 2 white pills on Wednesday afternoon, 3 blue on Thursday afternoon and 1 red on Sunday morning. (12)</td>
</tr>
<tr>
<td>D</td>
<td>Take 1 pill on Tuesday, 3 on Saturday, 3 on Monday and 1 on Thursday. (8)</td>
<td>Take 2 pills on Sunday afternoon, 3 on Thursday morning, 3 on Monday morning and 1 on Monday afternoon. (12)</td>
<td>Take 1 white pill on Tuesday morning, 2 red on Monday morning, 1 blue on Friday afternoon and 2 blue on Sunday morning. (16)</td>
</tr>
</tbody>
</table>

1 Represents number of components to be remembered per instruction.

Administration. In the auditory condition, the examiner read the instructions to the participant. The pills and pill container(s) were blocked from the participant’s view while the instruction was being given, and then presented once the instruction was completed.

Each instruction was heard only once. In the visual condition, instructions were typed in 18 pt. Helvetica font on 8.5 x 11” sheets of paper in landscape orientation. Participants were instructed to read each instruction silently only once, and indicate when they had completed reading it. The instruction was then removed from view and participants were presented with the pills and pill container(s). In both conditions, participants were not
given a time limit for putting the pills into the pill container, and encouraged to guess or state partial components of the instructions they remembered.

Two trials of each level and sublevel (A through D) were presented. Testing was discontinued within a level when both trials of a sublevel were missed. Testing continued at sublevel A of the next level. For instance, if a participant missed both trials of instructions at Level 1C, then the instructions at Level 1D were not presented. Rather, the next instructions presented were Level 2A.

Scoring. Performance on the experimental pill task was scored in two ways. The first was a method of load scoring where more difficult items were assigned a greater number of points (all or nothing load scoring) as described by Conway et al. (2005). Using this method, points were awarded when participants recalled all components of either trial of an instruction correctly. Point values ranged from one to four for Levels 1A through 1D, one and a half to six for Levels 2A through 2D, and two to eight for Levels 3A through 3D. The point values for each level are shown in Table 4. Items with the same number of components (e.g. Level 1B, Level 3A) were awarded the same number of points. For instance, participants were awarded two points for the correct configuration of the Level 1B item “Take 1 pill on Wednesday and 3 on Monday”, which comprised four components (number of pills x 2, day x 2). In the same manner, two points were awarded for the correct configuration of the Level 3A item “Take 1 red pill on Saturday morning”, which also comprised four components (number of pills, day, time of day, color). Participants had to answer only one trial correctly in order to be awarded full
points. Conversely, extra points were not awarded if both trials of a particular item were correct. The maximum number of points possible was 45.

Raw scores were also tabulated for the experimental pill task. In this scoring method, the number of elements correctly recalled was tallied for each trial of an item. Half points were awarded for each element that was present but not paired correctly. For example, given the Level 2B item “Take 1 pill on Wednesday and 3 on Monday”, if a participant put 3 pills in the Wednesday compartment and 1 pill on the Monday compartment, a total of 3 out of 4 possible points was awarded (2 points for the correct days and a half point each for getting the number of pills correct even though they were not paired with the correct day). The raw scoring method differed from the load scoring method in that both trials of any item counted toward the total raw score. The maximum raw score possible was 180. Table 4 illustrates the scoring rubric for both methods.

Table 4
Maximum number of points possible using load and raw scoring methods for procedural instruction processing task

<table>
<thead>
<tr>
<th></th>
<th>Level 1</th>
<th></th>
<th>Level 2</th>
<th></th>
<th>Level 3</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Load Pts</td>
<td>Raw Pts</td>
<td>Load Pts</td>
<td>Raw Pts</td>
<td>Load Pts</td>
<td>Raw Pts</td>
</tr>
<tr>
<td>A</td>
<td>1</td>
<td>4</td>
<td>1.5</td>
<td>6</td>
<td>2</td>
<td>8</td>
</tr>
<tr>
<td>B</td>
<td>2</td>
<td>8</td>
<td>3</td>
<td>12</td>
<td>4</td>
<td>16</td>
</tr>
<tr>
<td>C</td>
<td>3</td>
<td>12</td>
<td>4.5</td>
<td>18</td>
<td>6</td>
<td>24</td>
</tr>
<tr>
<td>D</td>
<td>4</td>
<td>16</td>
<td>6</td>
<td>24</td>
<td>8</td>
<td>32</td>
</tr>
<tr>
<td>Total Possible</td>
<td>10</td>
<td>40</td>
<td>15</td>
<td>60</td>
<td>20</td>
<td>80</td>
</tr>
</tbody>
</table>

Clearance Task. During piloting of the experimental pill task, participants were observed to exhibit some degree of interference from previous items. To prevent
interference, a distracter task was administered within each level between items B and C, and C and D, and between levels. The task was not administered between items A and B, because these items were sufficiently short and participants demonstrated near 100% accuracy during pilot testing. If testing was not discontinued for a participant failing both trials of any item, the distracter task was administered a total of eight times. The distracter task involved a series of “Find the Differences” pictures taken from a children’s magazine (*Highlights for Children*). Two identical colored illustrations with subtle differences between the two, were presented side by side. Participants were instructed to find three to five differences between the two pictures, and to say them aloud. Generally, participants took between 20 and 30 seconds to complete the clearance task during each presentation. Performance on this task was not scored.

**Examiners**

Two female native English speakers administered all tests and instructions. The majority of participants (59) were tested by Examiner 1. The remaining 19 participants were tested by Examiner 2, and all belonged to the young adult group. Examiner 1 trained Examiner 2 on testing methods, and observed 10% of sessions to ensure procedures were being followed as trained and to double-score assessments for reliability purposes. High levels of agreement were obtained on point to point reliability measures (see Table 5).
Table 5
Point to point reliability between examiners on dependent measures

<table>
<thead>
<tr>
<th>Measure</th>
<th>Percent Agreement</th>
</tr>
</thead>
<tbody>
<tr>
<td>MMSE</td>
<td>100</td>
</tr>
<tr>
<td>Digit Span – Auditory</td>
<td>100</td>
</tr>
<tr>
<td>Digit Span – Visual</td>
<td>100</td>
</tr>
<tr>
<td>Word Span – Auditory</td>
<td>100</td>
</tr>
<tr>
<td>Word Span – Visual</td>
<td>100</td>
</tr>
<tr>
<td>Sentence Span – Auditory</td>
<td>100</td>
</tr>
<tr>
<td>Sentence Span – Visual</td>
<td>100</td>
</tr>
<tr>
<td>Experimental Task – Auditory (raw score)</td>
<td>100</td>
</tr>
<tr>
<td>Experimental Task – Visual (raw score)</td>
<td>99</td>
</tr>
</tbody>
</table>
RESULTS

The primary purpose of this study was to examine effects of presentation modality in young and older adults on four measures of language processing: digit span, word span, complex memory span and processing of procedural instructions. Secondary purposes were to investigate age differences on performance, and to determine whether adults were accurate about predictions on how modality would affect their performance.

Demographic Variables

By design, the two subject groups differed in age, but were equivalent in years of education (see Table 2). All participants scored above 26/30 on the MMSE, the value considered to be the cutoff for normal cognitive functioning (Lemsky et al., 1996); however the young and older groups differed in their mean MMSE scores by one point, a significant difference $F(1,77) = 31.60, p < .001$. Estimates of verbal IQ based on demographic variables (Barona et al., 1984) yielded no significant differences between the two groups $F(1,77) = 0.09, p = .76$.

Scoring of Procedural Instruction Processing Task

Two methods were used to score the experimental instruction processing task. In the load scoring method, points were awarded for recalling all elements in an instruction correctly in an all or none fashion, according to difficulty. In the raw scoring method, each correctly recalled element was awarded a point. The two scoring methods were highly correlated ($r = .94, p < .001$) and produced similar results. However, because the raw scoring method allowed for a greater range of scores, raw scores will primarily be
reported. Load scores will be reported only when they differ from the analyses in which raw scores were used.

**Effects of Modality and Age on Dependent Measures**

*Analyses.* Before examining the modality and age effects on the dependent measures, it was necessary to ensure that the two versions of the measures used were equivalent. Results of a one-way analysis of variance (ANOVA) indicated there were no significant differences between the two versions of: digit span $F(1, 77) = .00, p = .97$; word span $F(1,77) = .10, p = .76$; complex span $F(1,77) = .02, p = .89$; and the procedural instruction task $F(1,77) = .16, p = .69$. Alpha level was set at $p = .05$.

To determine the effects of modality and age on the span tasks and instruction processing task, scores were analyzed in a repeated measures ANOVA with modality (auditory, visual) as the within subject factor, and group (young, old) as the between subjects factor. Partial $\eta^2$ is reported as a measure of effect size. Partial $\eta^2 = .01$ represents a small effect; partial $\eta^2 = .06$ represents a medium effect, and partial $\eta^2 = .14$ represents a large effect (Cohen, 1988).

Because younger adults scored significantly higher on the MMSE than older adults, $F(1,77) = 31.60, p < .001$ (see Table 2), an analysis of covariance (ANCOVA) with MMSE as the covariate was computed. Results of the analysis revealed that MMSE scores were not significantly related to the dependent variables. The relationship between MMSE and digit span approached significance $F(1,74) = 3.82, p = .054$. However, graphical analysis of the relationship between MMSE and digit span revealed that the homogeneity of slopes assumption was violated $F(1,74) = 8.85, p < .01$. This indicates
that the relationship between MMSE and digit span (i.e. the slopes of the regression lines) were not equal for the two groups. As none of the relationships between the covariate and the dependent measures were significant, the original ANOVA without the covariate was sustained.

*Effect of Modality on Dependent Measures.* There was a significant main effect of modality on all tasks except for load score on the pill task (Table 6). Participants scored higher on all measures when information was presented in the auditory modality.
Table 6
Repeated measures ANOVA for effects of modality and group

<table>
<thead>
<tr>
<th>Source</th>
<th>Measure</th>
<th>df</th>
<th>F</th>
<th>p (2-tailed)</th>
<th>$\eta^2$</th>
<th>Observed Power</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modality</td>
<td>Digit Span</td>
<td>1</td>
<td>8.28**</td>
<td>.005</td>
<td>.10</td>
<td>.81</td>
</tr>
<tr>
<td></td>
<td>Word Span</td>
<td>1</td>
<td>19.90***</td>
<td>.000</td>
<td>.21</td>
<td>.99</td>
</tr>
<tr>
<td></td>
<td>Sentence Span</td>
<td>1</td>
<td>13.71***</td>
<td>.000</td>
<td>.15</td>
<td>.96</td>
</tr>
<tr>
<td></td>
<td>Pill Load Score</td>
<td>1</td>
<td>3.27</td>
<td>.074</td>
<td>.04</td>
<td>.43</td>
</tr>
<tr>
<td></td>
<td>Pill Raw Score</td>
<td>1</td>
<td>5.32*</td>
<td>.024</td>
<td>.07</td>
<td>.62</td>
</tr>
<tr>
<td>Group</td>
<td>Digit Span</td>
<td>1</td>
<td>5.34*</td>
<td>.024</td>
<td>.07</td>
<td>.63</td>
</tr>
<tr>
<td></td>
<td>Word Span</td>
<td>1</td>
<td>82.29***</td>
<td>.000</td>
<td>.52</td>
<td>1.0</td>
</tr>
<tr>
<td></td>
<td>Sentence Span</td>
<td>1</td>
<td>89.92***</td>
<td>.000</td>
<td>.54</td>
<td>1.0</td>
</tr>
<tr>
<td></td>
<td>Pill Load Score</td>
<td>1</td>
<td>45.93***</td>
<td>.000</td>
<td>.38</td>
<td>1.0</td>
</tr>
<tr>
<td></td>
<td>Pill Raw Score</td>
<td>1</td>
<td>74.39***</td>
<td>.000</td>
<td>.50</td>
<td>1.0</td>
</tr>
<tr>
<td>Modality x Group</td>
<td>Digit Span</td>
<td>1</td>
<td>3.03</td>
<td>.086</td>
<td>.04</td>
<td>.41</td>
</tr>
<tr>
<td></td>
<td>Word Span</td>
<td>1</td>
<td>.21</td>
<td>.645</td>
<td>.00</td>
<td>.07</td>
</tr>
<tr>
<td></td>
<td>Sentence Span</td>
<td>1</td>
<td>.00</td>
<td>.984</td>
<td>.00</td>
<td>.05</td>
</tr>
<tr>
<td></td>
<td>Pill Load Score</td>
<td>1</td>
<td>.05</td>
<td>.817</td>
<td>.00</td>
<td>.06</td>
</tr>
<tr>
<td></td>
<td>Pill Raw Score</td>
<td>1</td>
<td>.17</td>
<td>.681</td>
<td>.00</td>
<td>.07</td>
</tr>
<tr>
<td>Error (Modality)</td>
<td>Digit Span</td>
<td>76</td>
<td>(0.65)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Word Span</td>
<td>76</td>
<td>(0.47)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Sentence Span</td>
<td>76</td>
<td>(0.33)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Pill Load Score</td>
<td>76</td>
<td>(32.93)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Pill Raw Score</td>
<td>76</td>
<td>(376.41)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Note:* Values enclosed in parentheses represent mean square errors.

* * $p < .05$; ** $p < .01$; *** $p < .001$
Table 7 shows the difference in performance between modalities (modality effect) for each of the tasks, expressed as a percentage of the average score of the two modalities, for both the young and older group. For both groups, the modality difference increased from the digit span to the word span and complex span tasks. The differences between modalities for the procedural instruction processing task were smaller than those seen for the word span task.

Table 7
Average, difference and percent difference scores between auditory and visual presentation across tasks

<table>
<thead>
<tr>
<th>Measure</th>
<th>Young Average</th>
<th>Old Average</th>
<th>Difference</th>
<th>Percent Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Digit Span</td>
<td>6.68</td>
<td>6.11</td>
<td>0.15</td>
<td>2.25</td>
</tr>
<tr>
<td>Word Span</td>
<td>5.59</td>
<td>4.14</td>
<td>0.44</td>
<td>7.87</td>
</tr>
<tr>
<td>Sentence Span</td>
<td>3.22</td>
<td>1.95</td>
<td>0.34</td>
<td>10.56</td>
</tr>
<tr>
<td>Pill – Load</td>
<td>27.05</td>
<td>17.49</td>
<td>1.45</td>
<td>5.36</td>
</tr>
<tr>
<td>Pill – Raw</td>
<td>140.74</td>
<td>98.07</td>
<td>5.89</td>
<td>4.19</td>
</tr>
</tbody>
</table>
**Effect of Age on Dependent Measures.** A significant main effect of age on all tasks was found. Younger adults scored higher on all measures than older adults.

**Interaction of Modality and Age.** No interactions between age and modality were observed. Both young and older participants performed better in the aural condition.

**Performance on Simple and Complex Span Measures.** Figure 3 depicts the scores of young and older adults by modality for the digit span, word span and complex memory span tasks. Modality was significant in all cases $F(5,72) = 7.60, p < .001$, partial $\eta^2 = .35$, in that auditory presentation resulted in higher span scores than visual presentation. Moreover, the effect sizes were medium for digit span (partial $\eta^2 = .10$) and large for word span (partial $\eta^2 = .21$) and complex memory span (partial $\eta^2 = .15$). Performance on the span tasks also showed a significant age effect $F(5,72) = 30.25, p < .001$, partial $\eta^2 = .68$, with younger adults scoring higher than older adults. Again, the effect sizes were medium (digit span, partial $\eta^2 = .07$) to large (word span, partial $\eta^2 = .52$; sentence span, partial $\eta^2 = .54$).
Figure 3
Performance of Young and Older Adults on Span Measures by Presentation Modality
Performance on the Procedural Instruction Measure. Figure 4 shows performance by modality of young and older adults on the procedural instruction task, using both load scores and raw scores. Although means for both types of scores were higher with auditory presentation, the modality effect was only significant for the raw scores \( F(1,76) = 5.32, p < .05, \text{ partial } \eta^2 = .07 \). As expected, young adults scored significantly higher than older adults on this task, whether load scores were used \( F(1,76) = 45.93, p = .001, \text{ partial } \eta^2 = .38 \) or raw scores were used, \( F(1,76) = 74.39, p = .001, \text{ partial } \eta^2 = .50 \).
Figure 4
Performance of Young and Older Adults on Procedural Instruction Processing Task by Presentation Modality
Errors on Complex Span Task. Participants’ intrusion and omission errors made during the complex span task were analyzed in a 2 x 2 ANOVA with modality (auditory, visual) and error type (omission, intrusion) as within subject factors and group (young, old) as a between subjects factor. Of the participants in the young group, error data was only available for the 21 participants tested by Examiner 1. Because the group sizes were unequal, analyses were carried out using Type III sum of squares and un-weighted means (Becker, 1999). There was a significant main effect of group $F(1,56) = 28.34, p < .001$, partial $\eta^2 = .34$ in that overall, older adults made more errors than younger adults. The interaction of modality and error type was also significant $F(1,56) = 8.83, p < .01$, partial $\eta^2 = .14$. Post-hoc comparisons were performed using the Sidak adjustment for multiple comparisons, revealing that for both groups, there were significantly more omission errors ($M = 20.45, SE = 1.76$) than intrusion errors ($M = 9.70, SE = 1.38$) in the visual modality than the auditory modality. No other interactions were significant. Table 8 shows the mean intrusion, omission and total errors across modalities for both the young and older groups.
Table 8
Means and standard deviations of omission, intrusion and total errors across modalities for both groups

<table>
<thead>
<tr>
<th>Error Type</th>
<th>Young</th>
<th>Old</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Auditory</td>
<td>Visual</td>
</tr>
<tr>
<td>Omission</td>
<td>10.2 (5.3)</td>
<td>17.1 (6.9)</td>
</tr>
<tr>
<td>Intrusion</td>
<td>5.6 (6.5)</td>
<td>7.8 (6.8)</td>
</tr>
<tr>
<td>Total</td>
<td>15.8 (7.9)</td>
<td>24.9 (5.4)</td>
</tr>
</tbody>
</table>

In tables 9 and 10, the percentage of young and older participants who passed each level for auditory and visual presentation, respectively, are given. To pass a level, participants had to attain a perfect score on at least one of the two trials. For the young group, the largest drop-offs in individuals passing a level occur between Levels 1C and 1D, 2B and 2C, and 3A and 3B for both presentation conditions. For the older group, floor effects were evident for the hardest levels in both presentation conditions.
Table 9. Percentage of young and older adults passing each level – auditory presentation

<table>
<thead>
<tr>
<th></th>
<th>1</th>
<th>2</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Young</td>
<td>Old</td>
<td>Young</td>
</tr>
<tr>
<td>A</td>
<td>100</td>
<td>97.3</td>
<td>100</td>
</tr>
<tr>
<td>B</td>
<td>97.6</td>
<td>83.8</td>
<td>80.5</td>
</tr>
<tr>
<td>C</td>
<td>85.4</td>
<td>48.6</td>
<td>34.1</td>
</tr>
<tr>
<td>D</td>
<td>29.3</td>
<td>10.8</td>
<td>4.9</td>
</tr>
</tbody>
</table>

Table 10. Percentage of young and older adults passing each level – visual presentation

<table>
<thead>
<tr>
<th></th>
<th>1</th>
<th>2</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Young</td>
<td>Old</td>
<td>Young</td>
</tr>
<tr>
<td>A</td>
<td>100</td>
<td>100</td>
<td>97.6</td>
</tr>
<tr>
<td>B</td>
<td>100</td>
<td>54.1</td>
<td>80.5</td>
</tr>
<tr>
<td>C</td>
<td>87.8</td>
<td>24.3</td>
<td>36.6</td>
</tr>
<tr>
<td>D</td>
<td>41.5</td>
<td>5.4</td>
<td>7.3</td>
</tr>
</tbody>
</table>
Another way these data can be analyzed is by comparing performance on levels with the same number of components. For instance, the Level 1B instruction “Take 1 pill on Wednesday and 3 on Monday” has the same number of components as the Level 3A instruction “Take 1 red pill on Saturday morning,” but the two differ in the number of propositions. In the case of the former, the four components (number of pills x 2, days x 2) are organized as an instruction with two propositions, whereas the latter instruction is organized as an instruction with one proposition involving more qualifiers. In this case, the number of propositions also corresponded to the number of actions required to complete the instruction. There were four pairs of instructions that had the same number of components, but differed in their propositional structure. Table 11 presents examples of pairs of instructions with the same number of components, differing in number of propositions.

To assess whether propositional organization had an effect on performance, 2 x 2 x 2 ANOVA was computed with modality and instruction complexity (number of propositions) as within subjects factors, and group as the between subjects factor. As expected, there was a significant main effect for group across all levels of instruction complexity $F(4,52) = 8.10, p < .001$, partial $\eta^2 = .38$. Moreover, significant effects of number of propositions were found for all but the most difficult (Level 2C vs. 3D) instructions. Examining pairs of instructions with the same number of components revealed that participants performed better on the instruction that integrated more components but had fewer propositions (e.g. Level 3A) over the instruction that had fewer components but more propositions (e.g. Level 1B). Significant interaction effects
between modality and instruction complexity were found for: four elements in the visual modality, six elements in the visual modality and eight elements in both the visual and auditory modality ($p < .05$). In all cases, the higher level (more components, fewer propositions) instruction resulted in better performance. One weakness in this analysis is that because the number of participants who passed each level decreased with increasing complexity (see Tables 9 and 10), there were unequal cell sizes in carrying out the analysis. However, ANOVA can be rather robust to cell size violations, this issue is not likely to invalidate the results (M. Borgstrom, personal communication, April 20, 2006).
Table 11
Sample instructions of levels with identical number of components showing significant differences in performance by young and older adults

<table>
<thead>
<tr>
<th>Number of components</th>
<th>Level 1B</th>
<th>Level 3A</th>
<th>Level 1C</th>
<th>Level 2B</th>
<th>Level 1D</th>
<th>Level 3B</th>
<th>Level 2D</th>
<th>Level 3C</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>Take 1 pill on Wednesday and 3 on Monday.</td>
<td>Take 1 red pill on Saturday morning.</td>
<td>Take 2 pills on Thursday, 1 on Sunday and 1 on Friday.</td>
<td>Take 3 pills on Saturday afternoon and 1 on Monday morning.</td>
<td>Take 1 pill on Tuesday, 3 on Saturday, 3 on Monday and 1 on Thursday.</td>
<td>Take 2 white pills on Tuesday afternoon and 1 white on Thursday afternoon.</td>
<td>Take 2 pills on Sunday afternoon, 3 on Thursday morning, 3 on Monday morning and 1 on Monday afternoon.</td>
<td>Take 2 white pills on Wednesday afternoon, 3 blue on Thursday afternoon and 1 red on Sunday morning.</td>
</tr>
</tbody>
</table>
Young and Older Adults’ Predictions of Modality Preference

A secondary research question was to determine whether participants could predict which modality would yield better performance on span and language processing measures. To answer this question, an ANOVA was carried out to determine the effect of preference (auditory, visual, no preference) on performance on experimental measures. A little under half of the sample (49%) stated they had no preference for one modality over the other. Of the remaining, 32% stated a preference for the visual modality, and 19% stated a preference for the auditory modality. Results of the 2 (modality) x 3 (preference) ANOVA revealed no significant effects of preference on any of the experimental measures in either modality. Counts of the number of individuals within each modality preference who actually performed better in that modality were tallied across all participants combined. Of the 19% of the sample who chose the auditory modality as their preferred modality, 67% were accurate, based on performance across all tasks. Of the 32% of the sample who predicted the visual modality would be preferred, 16% were accurate, and of the 49% who did not have a preference for either modality, 47% of them were accurate. Figure 5 presents predicted modality preference expressed in a percentage of the total sample, and the actual percentage of the sample that performed better in each modality by task.
Figure 5
Predicted and actual performance across tasks by modality preference

### Predicted and Actual Performance Across Measures by Modality Preference

<table>
<thead>
<tr>
<th>Measure</th>
<th>Predicted</th>
<th>Digit Span</th>
<th>Word Span</th>
<th>Complex Span</th>
<th>Instruction Processing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Predicted</td>
<td>19</td>
<td>32</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Digit Span</td>
<td>42</td>
<td>29</td>
<td>20</td>
<td>44</td>
<td></td>
</tr>
<tr>
<td>Word Span</td>
<td>56</td>
<td></td>
<td>20</td>
<td>44</td>
<td></td>
</tr>
<tr>
<td>Complex Span</td>
<td>54</td>
<td></td>
<td>39</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Instruction Processing</td>
<td>51</td>
<td></td>
<td></td>
<td>44</td>
<td></td>
</tr>
</tbody>
</table>

- **Auditory better**
- **Visual better**
- **No Preference**
Predictors of Performance on Procedural Instruction Task

Measures of working memory span and primary memory span have been shown to predict language comprehension scores (Daneman & Merkle, 1996). Therefore, it was expected that these measures would also be significant predictors of the procedural instruction task in this study. However, because age effects were significant in the span measures, as well as the procedural instruction task \( (F(1,76) = 74.39, p = .000, \text{partial } \omega^2 = .50 \text{ for raw scores}) \), it was necessary to examine contributions of span capacities independent of age. To address this research question, a series of hierarchical regression models tested the hypotheses that controlling for word span and complex span would substantially reduce the age effect on the procedural instruction task. Digit span and MMSE were also included in these analyses, as they also showed significant age effects in this sample. For these analyses, the average scores for the digit span, word span, complex span and instruction processing tasks across auditory and visual modality were used. Table 12 shows correlations among dependent variables, with the effects of age partialed out.
Table 12
Correlations among dependent variables partialing out effects of age

<table>
<thead>
<tr>
<th>Variable</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pill - Raw</td>
<td>____</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Complex Span</td>
<td>.32**</td>
<td>____</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Word Span</td>
<td>.45**</td>
<td>.57**</td>
<td>____</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Digit Span</td>
<td>.52**</td>
<td>.40**</td>
<td>.54**</td>
<td>____</td>
<td></td>
</tr>
<tr>
<td>MMSE</td>
<td>.33**</td>
<td>.17</td>
<td>.14</td>
<td>.16</td>
<td>____</td>
</tr>
</tbody>
</table>

*p < .05, **p < .01

A preliminary regression model with age as the sole predictor of procedural instruction task performance was computed. As expected, age was a significant predictor, accounting for 50.2% of the variance (p < .001). Subsequent regression models included the span measures as a primary predictor, followed by age. This allowed for a comparison of the amount of variance accounted for by each span task with effects of age alone.

The first regression model used MMSE as a predictor of procedural instruction task performance, followed by age. The MMSE was a significant predictor, accounting for 34.1% of the variance (p < .001). However, age was still a significant predictor, accounting for an additional 21.6% of the variance (p < .001). Compared to the age-only model, adding MMSE as a predictor reduced the age effect by 57.0%.

The next models used digit span, complex span, and word span, followed by age in separate models. All span tasks were found to be significant predictors (p < .001), the percentage of the variance accounted for, as well as the reduction in the age effect
compared to the age-only model, are presented in Table 13. Addition of the word span task in the model reduced the age effect by the greatest margin (84.1%) followed by the complex span task (80.9%).

The final model included word span followed by sentence span as predictors of procedural instruction task performance, followed by age. This model reduced the age effect compared to the age-only model by the greatest percentage (89.2%). This result was identical whether word span or complex span was entered into the model first.

Table 13
Results of Hierarchical Regression Analyses Predicting Mean Procedural Instruction Task Score Using Span Scores and MMSE

<table>
<thead>
<tr>
<th>Predictor</th>
<th>$R^2$</th>
<th>Increase in $R^2$</th>
<th>$F$</th>
<th>df</th>
<th>Decrease in age effect</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>.502</td>
<td>.502</td>
<td>76.56***</td>
<td>1, 76</td>
<td></td>
</tr>
<tr>
<td>MMSE</td>
<td>.341</td>
<td>.341</td>
<td>39.26***</td>
<td>1,76</td>
<td>57.0%</td>
</tr>
<tr>
<td>Digit Span</td>
<td>.291</td>
<td>.291</td>
<td>31.13***</td>
<td>1,76</td>
<td>28.1%</td>
</tr>
<tr>
<td>Word Span</td>
<td>.524</td>
<td>.524</td>
<td>83.71***</td>
<td>1,76</td>
<td>84.1%</td>
</tr>
<tr>
<td>Complex Span</td>
<td>.458</td>
<td>.458</td>
<td>64.21***</td>
<td>1,76</td>
<td>80.9%</td>
</tr>
<tr>
<td>Word Span</td>
<td>.524</td>
<td>.524</td>
<td>83.71***</td>
<td>1,76</td>
<td>89.2%</td>
</tr>
<tr>
<td>Complex Span</td>
<td>.553</td>
<td>.029</td>
<td>46.44***</td>
<td>1,75</td>
<td></td>
</tr>
<tr>
<td>Age</td>
<td>.608</td>
<td>.054</td>
<td>38.20***</td>
<td>1,74</td>
<td></td>
</tr>
</tbody>
</table>

***$p < .001$
DISCUSSION

The primary research question in this study was whether modality of information presentation (auditory or visual) affects the ability of young and older adults to process linguistic instructions to execute a procedural task, a complex span task and two simple span (digit, word) tasks. Secondary questions were whether age affected performance and whether adults would be accurate in their beliefs about which modality they would perform better in. Three notable findings emerged from the study. First, both young and older adults recalled more information when it was presented in the auditory modality, regardless of the task. Second, age effects were present on all measures. Third, individuals were generally inaccurate in predicting which modality would result in better processing.

Effect of Modality on Performance

Digit Span Test. Young and older adults had significantly larger digit spans when items were presented in the auditory modality. In the literature, evidence supporting the superiority of aural presentation has been reported on simple span tasks assessing free recall of digits and words (see Kausler, 1994 for a review). Specifically, aural presentation has resulted in superior recall for the last items in a series (i.e. the recency portion of the serial position curve). Although a serial position analysis was not done in this study, the overall total number of items recalled was larger when presented in the auditory modality.

Word Span Test. The majority of participants showed a modality effect on the word span task, favoring auditory presentation. This result conflicts with previous
findings of better recall of words after visual presentation (Taub & Kline, 1976). The likely explanation for this effect is that in this study, participants were unable to review the words because they were presented individually and then removed from view. In the Taub and Kline (1976) study, participants had the opportunity to review the words because they were not removed after presentation. Indeed, Taub and Kline reported the disappearance of the visual modality advantage when the possibility for review of written stimuli was removed.

*Complex Memory Span Test.* Auditory administration of the sentence stimuli in Daneman and Carpenter’s (1980) sentence span task resulted in higher spans than visual administration for both age groups. Measures of complex memory span are usually administered in the auditory modality (Daneman & Merikle, 1996; Verhaeghen & Salthouse, 1997). The exception to this is the reading version of Daneman and Carpenter’s (1980) sentence span task. Although results from a meta-analysis (Bopp & Verhaeghen, 2005) suggest that older adults do better in the reading than the listening version of this task, no studies to date have directly compared performance on the two versions of the task in older adults.

*Procedural Instruction Task.* Both young and older adults performed better in the auditory presentation condition of the procedural instruction task. The task involved reading or listening to progressively longer sets of instructions and executing them, and was similar to the word span task in that gradually increasing amounts of verbal information had to be held in working memory. However, as the instruction task also required attention, processing of linguistic information and retention, it can also be
characterized as a test of working memory. However, this task differed from traditional measures of working memory (complex span tasks). In traditional complex span tasks, such as Turner and Engle’s (1989) operation span task, participants are required to answer yes/no to mathematical equations (e.g. Is (7 x 2) + 3 = 17?) and then remember unrelated words at the end of the operation. Thus, processing and storage are conceptualized as separate elements, measured by the separate components of their task. In this task, the processing requirement involved extracting meaningful information from the acoustic/visual signal, and the storage component involved retaining and acting upon progressively longer instructions. Therefore, in this task processing and storage were incorporated into the actual comprehension of the instruction.

Because the storage processes measured by the simple memory span task were also common to the complex span and instruction processing tasks, one could argue that the modality effect on the storage components accounted for the modality effect on the higher level tasks. Indeed, in a study conducted by Goolkasian and Foos (2002), varying the presentation modality of the to-be-remembered item (storage component) was the determining factor affecting both processing and span capacity. In their study, spoken words produced superior recall and recognition, compared to printed words. Further, presentation modality of the items to be stored interacted with the processing component of the task (presented in the auditory modality) in that sentence verification accuracy was higher and reaction times were shorter when the storage items were presented aurally. These results suggest that modality effects may interact with both the storage and processing components of any working memory task.
Size of the modality effect. Examination of the size of the modality difference across tasks (Table 7) revealed that the performance difference between modalities got larger as the difficulty (or processing requirements) in the span tasks increased for both groups. The digit span task, thought to be a measure of “pure” primary memory (Wingfield et al., 1988), required the fewest processing resources and was associated with the smallest difference between visual and auditory presentations. The complex span task, on the other hand, with its simultaneous storage and comprehension operations, had the largest difference between modality of presentations. It appears from these results that visual presentation is more detrimental to comprehension when processing requirements are greater. The exception to this was the difference between auditory and visual modalities on the instruction processing task. This difference was not as large as that of the word span or complex span measure, for either group. Perhaps the interaction between task complexity and presentation modality was not as great because procedural instructions are more natural and therefore performance is similar when instructions are presented in either modality. Complexity of task may be a major factor for the lack of consistent findings in previous studies of presentation modality.

What Accounted for the Modality Effects?

The auditory modality is an ontogenetically more established system. Normally hearing infants learn language through the auditory modality. Information processing through the visual modality occurs later in development, and is grafted onto an existing aural language comprehension system. Although there is no definitive account of
modality effects, previous investigators have proposed mechanisms for why the auditory modality would allow for superior language processing.

In early studies of the modality effect on simple span measures, superior recall of aurally heard items was attributed to the presence of a *precategorical acoustic store* (PAS; Crowder and Morton, 1969). The PAS is thought to maintain a sensory trace of the last few items of a list that persists for a few seconds. This sensory trace then supplements the information being rehearsed in short-term memory, resulting in superior recall in the auditory modality. Crowder and Morton proposed that while the PAS exists for acoustic stimuli, no such store exists for visual stimuli. Although the PAS can account for the modality effect seen for the last items on a list (recency portion of the serial position curve), it does not account for the superiority of auditory presentation for complex span tasks. An account of the modality effect on the complex span and instruction processing measures must provide for a mechanism where higher level processing of information coming in from either modality can take place.

**The Separate Streams Hypothesis**

Penney (1980; 1989) proposed a model to account for the superiority of aural presentation on measures of short-term memory. However, its properties may also account for modality effects on higher level tasks. According to the *separate-streams hypothesis*, the auditory and visual modalities are two different streams that have unique properties and represent information differently.

With auditory presentation, an A (acoustic) code is created. The A code portrays aurally presented information as a result of direct sensory and perceptual processing and
has strong temporal properties. The P (phonological) code, on the other hand, is an internally generated code and portrays information as a result of the individual’s transformation of a sensory-based trace. The P code is sequentially organized, but the information contained within it is not as strongly represented as in the A code. According to the separate streams hypothesis, information heard through the auditory modality generates both an A code and a P code, whereas visually presented information only generates a P code. As the A code is hypothesized to be more durable than the visual sensory code, recall is better for information in the auditory modality. Information supporting the superiority of the A code over the P code comes from studies investigating interference and suppression effects (see Penney, 1989 for a review).

The separate streams hypothesis is an extension of a theory of knowledge acquisition termed the proceduralist view (Kolers & Roediger, 1984) where “knowledge and its representation in memory are not independent of the way in which the knowledge was acquired” (Penney, 1989, p. 399). This view is in contrast to the traditional view, which holds that meaning is extracted from a sensory stimulus, and perceptual aspects of the stimulus are not as important as the semantic content (Bransford & Franks, 1972; Sachs, 1967). According to the proceduralist view, modality effects in short-term memory processing are an integral part of the memory trace, and are therefore reflected in higher level cognitive operations.

With auditory presentation, further processing of incoming information can occur because the A code is not as susceptible to the fading that occurs when only a P trace is available. This theory also explains why some investigators (Taub & Kline, 1976; Dixon
et al., 1982; Corgiat et al., 1989) found an advantage for items presented in the visual modality. In these cases, the visual information was present for review. This theory proposes that the visual stream has a stronger spatial component (compared to the auditory streams’ stronger temporal component), which actually predicts that simultaneous presentation (allowing information to be present for review) will advantage the visual modality. In fact, research investigating simultaneous versus sequential presentation of words has confirmed that when words are presented all at once (simultaneous presentation), participants demonstrate superior recall than when they are presented with words in sequential fashion (Frick, 1985; Johansson & Nilsson, 1979).

**Effect of Age on Language Processing Measures**

All four language processing measures in this study were associated with a significant effect of age, with younger adults performing better than older adults. Although age effects on a range of cognitive tasks have been widely reported in the literature (Kausler, 1994; Park & Schwartz, 2000), the digit span task is one where there have been reports of no age effects (Bäckman et al., 2001; Wingfield et al., 1988). As discussed previously, this is likely due to the fact that span measures are traditionally only administered in the auditory modality. The findings of this study suggest that visual presentation of these span measures results in poorer processing. The discrepancy between these results and previous results may be accounted for by the fact that in this study, the digit span task was presented in both auditory and visual modalities separately. In fact, when the group means of young and older adults on the digit span task in only the auditory condition were compared, no age effect was present $t(76) = 1.21, p = .22$. This
finding suggests that auditory administration of span tasks may mask the true effects of aging on primary memory systems.

Contrary to digit span, the evidence for age effects on word span tasks is more straightforward (Salthouse & Babcock, 1991; Wingfield et al., 1988) and results of this study were in line with previous reports. Young adults had significantly larger word spans than older adults. It is hypothesized that word span requires more extensive identification processing, as the pool of items that words are drawn from is much greater than the pool of digits.

As predicted from the literature (Bopp & Verhaeghen, 2005; Carpenter, Miyake & Just, 1994), performance on Daneman and Carpenter’s (1980) sentence span task showed a significant effect of age. Older adults had lower span scores and greater omission and intrusion errors than younger adults on this task. As this is a task that is purported to measure working memory, the relationship between performance on this task and the procedural instruction task was of particular interest. A number of reports in the literature have attributed the age-related changes in language comprehension to age-related changes in working memory capacity (Dede et al., 2004; McCabe & Hartman, 2003; Van der Linden et al., 1999); therefore it was expected that the procedural instruction task (which required storage and processing of information) would show an age effect. In fact, this was the case. Further, because the processing and storage requirements of the complex span task and the procedural instruction task were similar, it was expected that age differences on this task could be predicted by performance on the complex span task.
Predictors of Performance on the Procedural Instruction Task. In actuality, all of the span measures, and even the MMSE, accounted for part of the age-related variance in performance on the instruction processing task. However, the word span task and the complex span task were the best predictors, with word span actually accounting for more of the variance than complex span (see Table 13). There are two interpretations for this finding. The first is that the procedural instruction task was merely a harder version of the word span task. The stronger relationship between word span and the procedural instruction task reflects that both tasks measured similar processes. The second is that although the instruction processing task required working memory, the construct of working memory, as defined by this task, was different from that conceptualized in the literature and measured by the complex span task.

In the literature, complex span tasks such as the sentence span task (Daneman & Carpenter, 1980), with its concurrent storage and processing requirements, is considered a measure of working memory. Differences in working memory capacity then, have been used as explanations for individual differences in language comprehension in aging. However, this introduces a circular line of reasoning, where ‘working memory’ is defined by what is measured by the ‘working memory’ task. In Daneman and Carpenter’s (1980) original paper, “working memory” capacity was viewed as a relatively fixed capacity among individuals, and language processing efficiency was a capacity that varied among individuals. This processing efficiency was what the Daneman and Carpenter task was originally conceptualized to measure. However, as Waters and Caplan (1996) discuss, this view rapidly became inverted: “Rather than viewing working memory as a resource
that was more or less fixed in individuals and sentence processing efficiency as the variable responsible for individual differences on the Daneman and Carpenter task, the perspective developed that the Daneman and Carpenter task measured a verbal working memory resource that varied across individuals” (p. 78).

Although there is no doubt that capacities for processing and capacities for storage are required to comprehend linguistic information, the type of processing and storage measured by the sentence span task seem to lack ecological validity when applied to the comprehension of language. Indeed, Waters and Caplan (2005) reported that older adults’ online processing of syntactic information was no different than that of young adults. They suggest that WM capacity, as measured by standard complex span tests (such as the sentence span test), is unrelated to on-line processing of syntactic and semantic attributes of sentences. In the procedural instruction processing task used in this study, the processing and storage requirements mirrored the comprehension requirements of everyday language, and therefore this task may have been easier than the complex span task, accounting for the smaller modality differences seen on this task. Further, the reason why word span performance was a better predictor than complex span on the instruction task may have been a reflection of these more naturalistic processing requirements.

Effects of Propositional Structure. The finding that both young and older adults had fewer errors in processing structurally complex (higher level) instructions can be explained by the inherent organization of the instructions. Kintsch and van Dijk (1978) proposed a model of prose processing as a propositional analysis in which text is viewed
as an integrated hierarchy of propositions. In applying this propositional analysis to the procedural instruction task, an instruction such as “Take 1 red pill on Saturday morning” is essentially one proposition with four qualifiers clarifying the instruction. On the other hand, the instruction “Take 1 pill on Wednesday and 3 on Monday” breaks down into two propositions with two qualifiers each. In terms of forming a hierarchical organization, it is easier to remember one proposition and add qualifiers to an existing structure. Indeed, the simpler hierarchical structure of the higher level instructions impose a natural ‘chunk,’ freeing up working memory resources (Cowan, 2005). Moreover, as there were no interaction effects in whether young and older adults performed better on propositionally complex instructions, this ability to process the internal structure of these procedural instructions appears to be a cognitive capacity unaffected by the aging process.

**Young and Older Adults’ Predictions of Modality Preference**

The third research question was to determine whether individuals could accurately predict which modality would yield better performance. The analyses revealed that there were no significant relationships between individuals’ preference for a modality and their actual performance. Both young and older adults were unable to reliably predict which presentation modality they would perform better in. In fact, nearly 50% of participants stated that they had no preference for one modality over another, when in actuality the majority of individuals performed best when information was presented in the auditory modality. Only 19% of study participants predicted they would perform better when hearing information; however two-thirds of this group were accurate in that they actually
did perform best when information was presented aurally. On the other hand, individuals who predicted they would perform better in the visual condition were the least accurate, only 16% of this group was correct in their prediction. Although the auditory modality was superior to the visual modality for processing linguistic information, individuals don’t seem to have a sense of this. These results suggest that in the absence of sensory deficits affecting either the auditory or visual modalities, information to be processed should be presented aurally.

**Summary**

Speech-language pathologists require an understanding of how healthy aging affects cognition, memory and sensory processing. Although basic knowledge of how language is processed in the auditory and visual modalities is integral for designing and implementing treatments for older adults with cognitive-communicative disorders, this information is lacking in the literature. Across four tasks ranging in complexity of processing requirements, both young and older adults were found to perform better when information was presented aurally. These results demonstrate the importance of considering modality of presentation when assessing individuals’ cognitive capacities, and presenting information. The results of this study corroborated findings in the literature of age effects on measures of primary and complex memory spans. However, this is the first study to systematically investigate effects of presentation modality on a procedural instruction task. As procedural information is a common aspect of everyday functioning, there is ecological validity in examining how processing and comprehension of instructions is affected by presentation modality. Finally, both young and older adults
were found to be unreliable in predicting the modality that would advantage their performance. Study results suggest that the ‘default’ method of presenting information aurally may in fact, be appropriate for most individuals.

Limitations and Future Directions

The dependent measures in this task were administered by a live person in a naturalistic environment. Although this was done to maximize generalizability to clinical environments, having a live person administer aural information introduces variability into the measures. Although steps were taken to ensure consistency of aural information presentation, variations in the examiner’s vocal intensity, rate and visual cues may have differed across participants. Moreover, as reading rates differ among individuals, it was difficult to control the length of time individuals spent reading information in the complex span and procedural instruction tasks. However, given that a modality advantage was still found for aural presentation, any benefits that may have been derived from longer exposures to visual information were not large enough to reduce this effect.

This study represents a first step in providing baseline information on how language is processed through either modality. The next step would be to use this information in considering how to effectively present information to individuals who may have cognitive-communicative disorders, sensory impairments, or neurologic disorders affecting auditory or written language comprehension. Investigations of factors that may advantage linguistic processing, such as allowing the opportunity to review in the visual modality, or presenting information in a dual-modality format will have implications for providing services to individuals with language comprehension deficits.
## APPENDIX A

BOOTHROYD ISOPHONEMIC WORD LISTS (BOOTHROYD, 1984)

<table>
<thead>
<tr>
<th>List 1</th>
<th>List 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>ship</td>
<td>jug</td>
</tr>
<tr>
<td>rug</td>
<td>latch</td>
</tr>
<tr>
<td>fan</td>
<td>wick</td>
</tr>
<tr>
<td>cheek</td>
<td>faith</td>
</tr>
<tr>
<td>haze</td>
<td>sign</td>
</tr>
<tr>
<td>dice</td>
<td>beep</td>
</tr>
<tr>
<td>both</td>
<td>hem</td>
</tr>
<tr>
<td>well</td>
<td>rod</td>
</tr>
<tr>
<td>jot</td>
<td>vote</td>
</tr>
<tr>
<td>move</td>
<td>shoes</td>
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## APPENDIX B

### WORD SPAN TASK VERSION A

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<th>3</th>
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<th>6</th>
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## APPENDIX C

### WORD SPAN TASK VERSION B

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</thead>
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<tr>
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<td>PHASE – BALL</td>
<td>FAST – SOIL</td>
</tr>
<tr>
<td>2</td>
<td>FILL – SEA – CHAIN</td>
<td>TEAM – SAVE – SLIGHT</td>
</tr>
</tbody>
</table>
REFERENCES


*Highlights for Children*. Columbus, OH: Highlights for Children, Inc.


