WORKING MEMORY IN SIMULTANEOUS INTERPRETERS

by

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Abstract

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Simultaneous interpretation is the continuous immediate oral translation from one language to another. It is physically and cognitively taxing and takes years to master. Most professional interpreters undergo substantial graduate-level training following a rigorous entrance selection process based on expertise in three or more languages and other cognitive abilities. Working memory is posited as a likely cognitive skill to distinguish interpreters from non-interpreter multilinguals. The findings in the literature to this regard are contradictory, however. Some studies indicate superior memory for interpreters relative to non-interpreters, while others do not.

This study investigated working memory differences between interpreters and non-interpreters with four tasks that deconstructed working memory in an attempt to isolate the locus of potential differences. Articulation rate (to gauge sub-vocal articulation) and non-word repetition tasks assessed phonological working memory. Cued recall assessed phonological recall independent of semantic information and vice versa. Reading span assessed complex storage and processing.

Since professional interpreters often work well past traditional retirement age and some cognitive and linguistic skills are known to decline with age, both older and younger individuals participated in the study. The participants included 13 older interpreters with a mean age of 56.3, 11 older non-interpreters with a mean age of 63.6, 12 younger interpreters with a mean age of 34.5, and 11 younger non-interpreters with a mean age of 31.8.

Performance differences depended on profession or age and the nature of the task. Interpreters outperformed non-interpreters for complex storage and processing as assessed via reading span and in phonological memory as assessed by non-word repetition. These advantages were independent of age. Professional groups did not differ on phonological and semantic storage as assessed via cued recall or on phonological processing as assessed by articulation rate. Age differences, independent of profession, were noted in cued recall, however. In phonological recall, older participants experienced both primacy and recency effects. Younger participants evidenced only primacy effects. In semantic recall, older participants demonstrated word-length effects. Younger participants did not. Results are discussed in terms professional experience and age changes.

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1. Introduction

1.1. Simultaneous Interpretation & Working Memory

In simultaneous interpreting (SI), an auditory message in a source language is orally translated into a target language as the message continues. Rather than word-by-word translation, which is essentially impossible across different languages, there is a focus on providing the meaning of a message. The interpreter's goal is to translate the important aspects of a message. The SI process taxes working memory (WM) in that the interpreter must concurrently keep the input in mind until a sufficient amount permits the interpreter to comprehend it, translate it, and produce a response at a quick rate. To perform this demanding task successfully, most professional simultaneous interpreters (PSIs) require years of training and practice. Some researchers maintain that PSIs have better WM as a result of their extensive training and practice in the task of SI (e.g., Darò, 1994). There is inconsistent evidence in the literature, however, as to whether or not PSIs actually have better working memory (WM) skills than non-interpreter multilinguals (NIMs).

The present study attempts to understand why contradictory evidence has been reported by looking at the separate capacities within WM, as described by Randi Martin and her colleagues (e.g., Martin, Shelton and Yaffee, 1994), as independently from one another as possible. Martin and colleagues found a dissociation for phonological (speech sound) and semantic (meaning) components of WM that is well supported in the general literature. Most of the literature regarding WM in interpreters, however, has not addressed this dissociation. It is possible that memory differences between interpreters and non-interpreters may lie in these individual capacities of either phonological or semantic working memory. Therefore, if these capacities are not individuated cognitively, performance differences may have been camouflaged in previous studies.

Martin and colleagues (i.e., Martin, Shelton and Yaffee, 1994), profiled two brain-damaged patients with comparable decreases in WM span (i.e., the number of items that can be retained in WM). The patients were college educated and assumed to be English speakers. No other information was reported. One patient's memory span, however, was relatively more impaired for phonological information than for semantic information whereas the other patient's memory span was relatively more impaired for semantic that for phonological information. The work of Nadine Martin and colleagues also supports the modularity of phonological and semantic representations in WM. Studying aphasic and normal language participants, Martin, Ayala, and Saffran (2002) and Martin and Saffran (1997) found evidence that semantic information influences primacy effects (i.e., better recall of list-initial items) and phonological information influences recency effects (i.e., better recall of list-final items).

The dissociability of WM is also seen with intact cognitive systems. Henk Haarmann and colleagues, for example, demonstrate the dissociation of semantic WM from other forms of working and long-term memory with their Conceptual Span Task (Haarmann, Davelaar, & Usher, 2003; Haarmann & Usher, 2001) and semantic category cued recall (Haarmann & Usher, 2001). Haarmann and Usher for example, found that word-length effects (i.e., better recall for shorter relative to longer words) that are associated with phonological loop function were absent in cued recall for semantic information. This suggests that semantic category cued recall invokes phonological rehearsal strategies to a lesser degree than do overt phonological tasks (e.g., serial order cued recall).

The modularity of WM is supported in neurophysiological studies as well. Crosson, Rao, Woodley, Rose, Bobholz, Mayer, Cunningham, Hammeke, Fuller, Binder, Cox, and Stein, (1999), using a carefully constructed control task, were able to locate different cortical areas for phonological versus semantic WM consistent with those cited in the literature via lesion studies. Areas of activation for semantic information included the left posterior inferior temporal lobe (near Brodmann's areas 20 and 21) and the left inferior frontal gyrus, anterior to Broca's area (near Brodmann's area 47). Brain mechanisms for phonological information included the inferior temporal-occipital junction and an area of the prefrontal cortex (near Brodmann's areas 44 and 46) independent of those seen for semantic activation. Studies with N-back tasks (i.e., where participants are presented with a series of items to remember and asked to recall one of the items depending on its position in the list) evidenced different areas of cortical activity for executive processing and phonological loop functions of WM. Smith and Jonides (1997) reported that activity for executive functions take place most dominantly in the dorsolateral prefrontal cortex, that rehearsal functions are localized to anteriorly to the premotor strip, supplementary motor and Broca's areas, and that storage is localized to post-parietal areas.

1.1.1. Working Memory Models

Among the models of WM best suited for addressing whether or not PSIs have better WM than NIMs is that of Baddeley and colleagues (e.g., Baddeley & Hitch, 1974; Baddeley 2000). Baddeley's model is appropriate, in part, because it is consistent with the finding that there are separate capacities for different types of information in working memory as mentioned above. Baddeley's model also proposes specific components of WM that account for a variety of behavioral phenomena noted in WM tasks (e.g., recency, primacy, length affects). The Baddeley model, in particular, explains WM for lists of information, which has been the focus in the SI literature to date and will be the primary focus of this investigation. Other WM models, such as that of Just and Carpenter (1992), focus more on WM that involves higher-level language processing, such as sentence comprehension, rather than the simpler list-item memory.

The goal of this study is to understand WM differences between interpreters and non-interpreters on the most basic level of memory storage and processing despite the fact that interpreters work principally at a phrase or sentence level. Phrase and sentence processing, in addition to WM, involves long-term memory and other cognitive processes such as morphological and syntactic processing. Therefore, when sentences are used in WM tasks it becomes difficult to pin-point the exact cognitive process or processes where differences across varied groups manifest. Once basic WM processing performance in

PSIs versus NIMs is clearly established, performance on higher level WM processing can be more appropriately addressed.

Baddeley and Hitch initially conceptualized a system involving three main components of WM (see Figure 1a). This model included an attentional system known as the central executive and two subordinate systems. One system, the visuo-spatial scratch pad, processes visual and spatial information. The other system, the phonological loop, manages verbal information. The phonological loop consists of a phonological store where information is held for about 2 seconds before it begins to decay. The second component is a rehearsal process that refreshes information in the store via subvocal articulation. The central executive, considered the most important aspect of WM (Baddeley & Gathercole, 1993), is a regulatory mechanism that controls information flow in WM, information retrieval from other memory systems, and information storage and processing in WM.

Recently, Baddeley (2000) has revised the model to include an episodic buffer (see Figure 1b). The buffer is a limited capacity storage system that is able to integrate various types of information such as visual and phonological information. This is important since many verbal WM tasks use visual stimuli. Similar to the components of the phonological loop, the episodic buffer is controlled by the central executive. The central executive can access the episodic buffer consciously and influence its contents by attending to an information source (e.g., LTM or the phonological loop). The episodic buffer was added to account for the recall and processing of prose and semantic information as well. Baddeley proposes that the buffer is a mechanism for recalling the gist of a message rather than verbatim information.

In summary, there is ample evidence of the modularity of phonological and semantic information in working memory from the brain-damage, cognitive psychological and neuropsychological literatures. There is also a distinction of phonological and semantic information in the SI process whereby semantic information may be more important to the SI process as it is the transfer of semantic information that is the ultimate goal of the process. Using the revised Baddeley model as a theoretical basis, we can look at semantic and phonological memory relatively independently. This should tell us how each contributes to the process of simultaneous interpretation.

1.2. WM in PSIs: Evidence from the literature

Many of the studies that have looked a WM in interpreters have used measures of memory span that reflect WM capacity. Table A profiles these studies and their outcomes. There are two basic types of span measures, those that use words and those that use sentences. In word-span tasks, WM capacity is established as the maximum number of items an individual is able to repeat back immediately following presentation of a list of words. In sentence-span tasks, also referred to as phrase- or reading-span tasks, by contrast, capacity is determined by the maximum number of sentences an individual can repeat the final word from following presentation. Word-Span measures are typically considered to be representative of phonological loop function because they show the effects of the phonological loop such as better recall for information at the beginning of a list (primacy), better recall for information at the end of a list (recency), and better recall for shorter relative to longer words (length effects). Recall that the phonological loop functions to store and refresh verbatim speech-sound information in WM. Sentence-span tasks generally reflect complex storage-and-processing in WM. Using sentence stimuli, then, would prevent one from determining precisely what may be contributing to group differences in basic WM (e.g., phonological storage, semantic storage, etc). Thus, use of word-list stimuli, rather than sentences, permits for relatively isolated testing of WM function. That is, word stimuli, unlike sentence stimuli, allows for assessment of phonological WM relatively independent of semantic WM and assessment of general WM in a relatively independent of long-term memory.

1.2.1. Evidence of Superior PSI Performance over NIMs

1.2.1.1. Word-List Stimuli.

There is evidence in the WM literature that employs word lists that suggests that PSIs have better phonological loop function than do NIMs. Darò and Fabbro (1994) and Padilla, Bajo, Cañas, and Padilla (1995), for example, report higher than average digit spans for interpreters relative to non-interpreters. Darò and Fabbro studied a group of 24 student interpreters as they participated in a series of digit span tasks. The student interpreters ranged in age between 22 and 27 (average age 24.5) and had been in SI training between 12 and 60 months (average 29 months) for 10 to 40 hours a week. They were described as highly proficient in their native Italian as well as two other languages among a set of four: German, English, Spanish, and French. The authors divided the participants into two groups according to what language they worked in. Group A performed the task in Italian and Group B performed in English. No details were reported regarding how group placement was determined.

Darò and Fabbro (1994) presented strings composed of digits from 1-9 binaurally over headsets. The series began with two sets of three digits, then two sets of four digits, up to two sets of 9 digits. Participants immediately recalled the numbers in the order they had been presented after the end of each set. The task yielded a span of 8.38 for Group A and a span of 8.90 for Group B. The combined average span was 8.65. These figures are higher than reported average of 7 digits in non-interpreters (Darò, 1995) and support the proposal that PSIs have better phonological loop function relative to non-interpreters.

In another study that compared PSIs, student interpreters, and NIMs, Padilla et al. (1995) found that PSIs had superior digit spans. They studied four groups of bilingual participants with varied experience with SI. One group of ten participants were practicing interpreters, five who were recent graduates of the School of Translators and Interpreters at the University of Granada and five who had been practicing in the field for about five years. These individuals had a mean age of 30 year. No other age-related information was reported. A second group of ten participants were third-year interpreting students described simply as having some SI training. No age information was reported for this group. A third group of ten participants were also students. This group of students, however, was in their second year of their program, and had training in translation but not

SI. Again, no age information was reported for this second group of students. A final, fourth group of ten participants were bilinguals with no translation or interpreting experience. Like the student groups, no age information was reported. There was also no other information regarding background history of the participants provided.

As in the study of Darò and Fabbro (1994), Padilla et al.'s (1995) participants listened to sets of digits and were asked to recall them in order of presentation. The task commenced with three sequences of four digits. Each set of sequences increased by one digit so that the second set had three sequences of five digits. Sets were presented in these increasing sizes until a participant was unable to recall the digits in order. The results indicated that the PSI group had significantly longer digit spans than the other groups. Although the group digit-span means were not directly reported, graph data indicate that the PSI group had spans just over 7 digits where the other groups had spans just over 6 digits. The authors note that the second-year students, without SI training, performed comparably to the NIM group.

Another recent study (Christoffels, 2006) looking at interpreters and highly proficient bilinguals also found statistically superior PSI performance using word stimuli as opposed to the digits used in the previously mentioned studies. The first of two control groups consisted of 39 Dutch/English bilingual university students who spoke Dutch as a first language. All had at least six years of formal education in English as a second language and used English textbooks for their university course-work. The second control group consisted of 15 Dutch teachers of English. The teachers had an average of 19 years experience teaching English in the Netherlands at the higher levels of secondary education. The experimental group of interpreters also included native Dutch speakers and used English as one of their languages of interpretation. The interpreters, teachers, and students had mean ages of 48.5, 43.5 and 21.1 respectively.

The Christoffels et al. (2006) participants saw words one at a time on a computer screen in sets of three to 10 words. They were then asked to recall each set in order after the presentation of the final word in its list. The task was executed in both Dutch and English. The results revealed statistically superior performance by the interpreters over both groups of non-interpreters. The interpreter group achieved word spans of 5.0 and 5.92 in Dutch and English respectively. The students achieved word spans of 3.59 and 3.05 in Dutch and English respectively. The English teachers achieved word spans of 3.8 and 2.4 in Dutch and English respectively

It is also worth noting superior PSI performance in word-list recall, a task that is somewhat similar to span measures like those mentioned above (i.e., word lists are presented and information from the list is recalled). Superior WM and phonological loop function, in particular, was supported by Padilla et al.'s (1995) study in another set of experiments that employed list recall with articulation suppression. Articulation suppression is a method commonly employed to assess phonological loop function. This method assesses the storage component of the phonological loop because it prevents subvocal articulation in the phonological loop to refresh information in WM.

The four Padilla et al. (1995) experimental groups participated in a series of word-list recall tasks with articulation suppression. In these tasks, participants read three lists of 16 printed words, presented at the rate of one word every three seconds. They articulated the nonsense syllable, "bla" repeatedly during list presentation. In a free-recall condition of this articulation suppression task, participants recalled each word list at the conclusion of list presentation. In a final-recall condition of this articulation suppression task, participants recalled as many words as possible after all three lists had been presented.

The PSI group recalled significantly more words than the NIM and novice groups in both free and final articulation suppression recall tasks. The raw data were not reported, but graph data indicate that the PSI group recalled approximately 55 words relative to the other groups whose performances approached only 40 words. This suggests that PSIs have better WM skills than NIMs, at least when the rehearsal process of the phonological loop is effectively removed from WM function. Padilla et al. (1995) ran this task without articulation suppression as well. The results of this second condition are discussed in the following section on performance parity.

Köpke & Nespoulous (2006) found a similar result under articulation suppression comparing professional simultaneous interpreters, student interpreters, bilingual speakers, and monolingual speakers. They used aural stimuli, however, in contrast to Padilla et al.'s (1995) print stimuli. Köpke & Nespoulous' professional interpreter group consisted of 21 individuals who ranged in age from 29 to 61 years (mean age 44.4 years) and had four to 35 years of interpreting experience. The student interpreter group consisted of 18 individuals, ages 23 to 38 years (mean age 26.2), and who were in their second year of studies and had just begun their training in simultaneous interpreting. There was one control group that consisted of 20 bi- and multilingual speakers who ranged in age from 27 to 63 years (mean age 44.7 years) and a second control group of 20 monolingual speakers who ranged in age from 18 to 26 (mean age 21.5). All testing was done in French, the dominant language of all the participants. All the multilingual participants, save the monolingual group, were highly proficient in at least English and sometimes other languages. No other specifics were given to what the languages were, how they were used, how they were acquired, etc.

In the Köpke & Nespoulous (2006) free-recall task, the participants heard word lists of 12 items while repeating the word, "bla". At the end of a list they recalled the words in any order. Surprisingly, the student interpreters had the best performance (mean of 5.2), followed by the professional interpreters (mean of 4.7), the monolingual speakers (mean of 4.37), and then the multilingual speakers (4.4). Group differences were significant ($F = 2.82$, $p = .045$), though post-hoc analyses did not reveal further significant differences. The authors reasonably propose that the data suggest the novice interpreter group out-performed the experts and that the experts out-performed the two non-interpreter control groups. Köpke & Nespoulous ran their free-recall task without articulation suppression in addition to a number of other tasks. These will be discussed in the following section on performance parity.

1.2.1.2. Sentence Stimuli.

As mentioned above, sentences are used in span tasks to assess WM capacity in addition to word lists. Padilla et al. (1995) also ran their four groups of participants in a reading-span task. The task was a Spanish adaptation of Daneman and Carpenter's reading-span task (1980). Recall that reading span is a complex-storage-and-processing task in contrast to the simple storage task aforementioned. Participants read sets of sentences presented one at a time then recalled as many final words from as many sentences as possible from a set. The number of sentences per set increased as the task progressed. The maximum number of final words recalled indicates what the authors called the participants' phrase span. Padilla et al.'s PSI group had significantly longer phrase spans than the other groups. Graph data for phrase span indicated spans of 5 for the PSI group and spans of just under 4 for the other groups. Again, as with the digit span task, the second-year students without SI training from this study, performed comparably to the NIM group.

Christoffels et al. (2006) also found superior PSI performance in a reading-span task. Their participants read aloud 42 English sentences in sets of two, three, four, and five. After reading the final sentence in a set, a beep sounded and the participant would recall the last word of each sentence. Significant group differences manifested with the interpreters outperforming the non-interpreters. The interpreter group achieved reading-span scores of 35.39 and 34.54 (out of a possible 42) in Dutch and English respectively. The teacher and student groups achieved reading-span scores of 32.06 and 30.73 and 34.00 and 31.13 in Dutch and English respectively.

An arguable interpreter advantage was found in a listening span task in the Köpke & Nespoulous (2006) study. The professional interpreters, student interpreters, multilinguals and monolinguals in this study listened to spoken sets of sentences. They repeated each sentence and were asked to remember the last word of each sentence. After a set was presented, the participants recalled the last word from each sentence in the order of presentation. The results indicated that the student interpreters to have the highest mean score (4.54) followed by the professional interpreters (3.91), then bilingual (3.51) and monolingual controls (3.45). No difference emerged between the two interpreter groups. Statistical significance was found only between the student interpreter and the non-interpreter groups however.

In summary, there are both simple storage and more complex storage-and-processing tasks that show PSIs have better working memory skills relative to NIMs. Simple storage advantages for PSIs are further substantiated by tasks employing articulation suppression that prohibit phonological rehearsal to refresh information stored in WM. Advantages for PSIs relative to NIMs were also seen for stimuli that were both aural and print in nature.

1.2.2. Evidence of Parity of WM Skill in PSIs & NIMs

The studies and tasks reviewed above suggest that PSIs have better WM skills than NIMs. One must note, however, that there are other studies and tasks that suggest there may be no WM differences between the groups. While Darò and Fabbro (1994) found statistically significant group differences, Padilla et al. (1995), Christoffels (2006), and Köpke & Nespoulous (2006) found mixed results. Chincotta and Underwood (1998) and Liu (2001) found no significant differences between PSIs and controls using similar tasks to those used in the studies mentioned above that did find group differences.

1.2.2.1. Word List Stimuli.

As mentioned in the last section, Padilla et al. (1995) ran their four participant groups in free- and final-recall word-list tasks. When forced to speak during stimulus presentation, PSIs outperformed NIMs in their ability to recall the words presented. When the tasks were run in an alternate condition, however, wherein participants simply listened to the lists and then recalled them, either immediately (free-recall) or after a delay (final-recall) as described above, no group differences manifested in the number of words recalled.

Results of digit span tasks also appear to demonstrate parity of performance. Contrary to Padilla et al.'s (1995) digit span results of significant group differences using auditory stimuli mentioned in the previous section, Chincotta and Underwood's (1998) findings indicate no significant differences in memory span for printed digits between student interpreters and NIMs. Chincotta and Underwood compared 12 student interpreters from the University of Turku with a minimum of 100 hours of experience interpreting between Finnish and English to a group of twelve Finnish English majors. The participants were all described to be Finnish dominant, Finnish-English bilinguals. No other information on language history or age was reported.

The participants saw four sets of digits presented one at a time, sequentially on a monitor. Each set began with two series of two digits and then two series of three digits increasing by one digit every series up to two series of 13 digits. Following a prompt tone at the end of each series, the participants orally recalled as many numbers as possible in both Finnish and English conditions. The stimuli were also presented in normal and suppressed conditions. In the suppressed condition, participants articulated the nonsense syllable “la-la” continually beginning four seconds prior to the initial stimulus presentation and ending four seconds after presentation of the last digit stimulus. The results indicated no significant differences between groups in mean digit span in either language.

Köpke & Nespoulous (2006) ran a series of word list tasks that, unlike most other studies looking at interpreters, addressed the dissociation of phonological and semantic WM. As mentioned earlier, they compared professional simultaneous interpreters, student interpreters, bilingual speakers, and monolingual speakers. Participants performed auditory word span tasks with real words, non-words, semantically similar words and phonologically related words.

In the span tasks, participants listened to word lists four to 12 words in length and repeated them back in order as best they could. Results of the span tasks revealed no significant differences across the groups. Also, as mentioned, they had performed a free-recall task without articulation suppression. Recall that under articulation suppression group differences were found. Without articulation suppression, however, Köpke &

Nespoulous, like Padilla et al. (1995), did not find significant group differences. Mean scores and statistics were not reported for the free recall without suppression.

Köpke & Nespoulous' (2006) participants also performed phonological and category cued recall tasks. In the phonological condition, after listening to the word list, the participants were given a probe word and had to report if the probe word rhymed with one of the words in the list by responding, "yes" or "no". In the category condition, participants had to report if the probe word belonged to the same semantic category as one of the words in the list. No group differences were noted in the phonological condition. The category condition revealed group differences by language background only. The multilingual groups all performed better than the monolingual group. There was a tendency, nonetheless, for the interpreter groups to achieve higher task scores than the non-interpreter groups. The phonological scores were not reported, but the category scores indicated that the novice interpreters obtained the highest mean score (9.2) followed by the expert interpreters (8.49), the bilingual controls (8.2), and the monolingual controls (7.18). The authors do not report p values for these data, so it is not know if this tendency is an actual pattern that might become significant with more power. The tendency is mentioned here because it is noted often in the literature.

1.2.2.2. Sentence Stimuli.

In addition to tasks using word-list stimuli, performance in tasks using sentences also suggests a parity of performance between interpreters and non-interpreters. Liu (2001) conducted a study that compared 13 professional interpreters, who had at least one year of training and two years of professional experience, to two groups of student interpreters. One group of 12 students had a year and a half of SI training. The other group of 11 students had just begun SI study. All the participants were native Mandarin speakers who spoke English as a second language. Some participants were described as having native-like proficiency in both languages. There was no indication of which participants this description pertained to, however. Liu noted that the students were enrolled in programs in Taiwan and California, though the number of students in each program was not reported. The working situation of the PSIs was also not included. No other details pertaining to language history or age were provided.

Liu's phrase-span task is another adaptation of Daneman and Carpenter's (1980) reading-span task. Instead of reading, her participants listened to a series of unrelated spoken English sentences 13 to 16 words in length. Each series consisted of five sets of sentences, beginning with two sentences and progressing to five sentences by an increase of one sentence per series over the course of testing. At the end of each set, the participants wrote down as many of the last words from the sentences as they could remember. The number of final words recalled indicated a participant's phrase span. Liu found no significant differences in phrase span across groups. There was a tendency, nonetheless, for professionals to achieve higher scores than students and for students with more interpreting experience to achieve higher scores than those with less experience. Mean scores for professional interpreters, advanced students, and beginning students were 3.3, 2.91, and 2.59 respectively. Similar to the Köpke and Nespoulous (2006) tendency mentioned earlier, the authors do not report p values to judge whether or not this tendency is an actual pattern.

The Köpke and Nespoulous (2006) listening span task mentioned in the section on interpreter advantage is also appropriate to mention here. While it was true that the student interpreters performed significantly better than the non-interpreters, the professional interpreters did not. It is also worth mentioning, however, that the professional interpreters were older and performed in the direction of better performance relative to the non-interpreters. These two facts in conjunction with the finding that no significant differences were found between the novice and professional interpreters on this task, suggests there is an advantage for professionals that this task may not have been sufficiently sensitive to detect.

In sum, one set of studies evidences statistically significant superiority of PSIs over SI students and NIMs, with a subset showing student interpreters having the advantage over the other two groups, while a second set does not. The second set, however, often shows absolute differences in the direction of interpreter (student or professional) superiority in WM. Thus, one may conclude that the 'no-difference' findings may reflect a small but real effect in conjunction with the relatively small sample sizes and the range of inter-individual differences among participants. Moreover, that there were studies whereby the same participants either evidenced group differences or not, depending on the nature of the stimuli and the task (e.g., Padilla et al., 1995; Köpke & Nespoulous, 2006) suggests that task differences are crucial in determining whether group differences will be manifest. In addition, contributions of phonological versus semantic working memory involved in a task should be gauge and controlled and considered when assessing performance.

1.3. Why the Contradictory Findings?

There are a number of possibilities as to why some studies indicate better WM function in PSIs in comparison to NIMs and others do not. These may include participant selection (e.g., the number of participants, the languages they spoke, amount of SI training, proficiency, age at testing, and use of languages tested), the nature of the stimuli (e.g., digits versus words, printed versus aural presentation, and cross-linguistic issues such as longer versus shorter articulation duration of stimuli), and the procedures (e.g., tasks to assess the various components of WM such as the phonological loop versus the episodic buffer).

1.3.1 Small N

Consider, first, the participants selected to take part in each experiment. Many of the studies surveyed here had small participant groups. A small number of participants does not yield strong statistical power and compromises external validity. This presence of a small N is important to note since individual performance varied and there was a tendency for higher raw score achievement with increased levels of SI experience relative to less or no SI experience across the reported studies. It stands to reason that these tendencies might have become a statistically significant difference had the groups been larger.

1.3.2. Limited Background Information

Consider, also, the limited background information and perhaps control regarding language history as a contributing factor to the contrastive findings across studies. Pertinent information to collect and control for would include the manner in which languages were acquired, the order of language acquisition, the nature and degree of language use, and the phonological, orthographic and morpho-syntactic nature of the languages that the participants know. Insufficient control on these variables contributes to heterogeneity of the participant groups and exacerbates the problems of a small N. Collecting such information is also important because these variables can influence language proficiency. Ascertaining proficiency is important because competency in a particular language influences WM performance in that language. Thorn and Gathercole (2001), for example, show that WM capacity measured by nonword repetition is related to proficiency as measured by vocabulary knowledge in the language of testing. The importance of the proficiency issue regarding interpreters has also already been demonstrated. Recall that the findings in the Christoffels' (2006) study revealed significant differences between PSIs and NIMs in sentence-span tasks when performing in L2 but not L1, despite high L2 proficiency in both groups.

1.3.3. Age

Another aspect regarding background that may account for the discrepancy in findings is the age range of the participants. The literature shows that, as we age, certain aspects of language performance, like lexical retrieval and semantic short-term memory, deteriorate (e.g., Nicholas, Obler, Albert, & Goodglass, 1985; Haarmann, Ashling, Davelaar, & Usher, 2005). The ages of the participants in most of the studies surveyed above were not reported adequately to make proper speculations regarding age as a performance factor. Table B lists the age information as reported by the studies mentioned. Since age can interact with performance it should be controlled for carefully in cognitive and linguistic experiments.

1.3.4. Experience & Expertise

Barbara Moser-Mercer and colleagues (2007) have shown that the source of difficulty in interpreting changes for interpreters as they move from novice to more expert status. This sets interpreting experience as a potential locus for the conflict in the literature regarding superior working memory skills in interpreters relative to non-interpreters. The range of interpreting experience reported in the working memory/interpreter literature ranges greatly both within and across studies (See Table B). There is no consistency or specificity to the data. Some authors report experience in hours, others report experience in terms of years. The lack of consistency documenting experience makes it difficult to compare studies and discern a definitive pattern. What does manifest with relative clarity, however, is a continued discrepancy. Recall, for example, that Padilla et al. (1995) and Köpke and Nespoulous (2006) both included novice and expert interpreters in a task of free recall involving articulation suppression. Padilla and colleagues found that interpreters with five years experience out-performed novice interpreters who had only recently graduated from an interpreting program. Köpke and Nespoulous, on the other hand, showed that novice interpreters, who had just begun their simultaneous interpreting training, out-performed professionals with four to 35 years interpreting experience.

Köpke & Nespoulous (2007) also suggest that PSIs, relative to non-interpreters, may have other skills that give them an advantage in various short-term memory skills. They suggested PSIs may, for example, also be highly skilled readers (arguably accounting for better reading span performance), be trained in consecutive interpreting, and may be exceptionally good at problem solving.

1.3.5. Cross-linguistic issues

1.3.5.1. Language Differences.

Cross-linguistic differences are also noted to manifest in WM tasks. Memory span, as mentioned, is sensitive to word length. Welsh-dominant bilinguals, for example, evidenced greater digit span in English than in Welsh (Ellis and Hennelly, 1980). The authors proposed this was due to Welsh digit names being longer than English digit names. This proposal is supported in the cross-linguistic differences we saw in the Darò and Fabbro (1994) study mentioned earlier where Group A, who performed the task in Italian, had a slightly lower span than Group B, who performed the task in English despite being all being Italian dominant speakers. Italian digits have more syllables than their English counterparts so it is not surprising that Darò and Fabbro's results are similar to those of Ellis & Hennelly.

1.3.5.2. First Versus Second Language Performance.

The language of testing is another cross-linguistic issue that should be considered when trying to understand the discrepancy in the literature. The field to date, however, does not provide sufficient evidence to make determinations regarding L1 versus L2 performance. The language background of participants and, at times, even the language of testing was not thoroughly documented in the literature. Table A shows a breakdown of the participants from the aforementioned studies regarding native language versus the language of testing.

There is no pattern that emerges to suggest if discrepancy in the literature is due to being assessed in a first, native or dominant language versus a secondarily acquired less dominant language. Performance seems to be consistent cross-linguistically regardless of language. Of the span studies that tested in both L1 and L2, two found PSIs to be superior in both languages (Darò and Fabbro, 1994; Christoffels, 2006). The third study (Chincotta and Underwood, 1998) found PSIs and MINs to have comparative skills, also in both languages.

Free recall results were reported in both the Padilla et al., (1995) and the Köpke and Nespoulous (2006) studies. Köpke & Nespoulous tested only in L1 and found PSI superiority under articulation suppression. Padilla et al. also only found group differences under articulation suppression, but did not report the language of assessment, unfortunately. The results of the sentence stimuli are equally as uninformative for forming a consensus as the word stimuli on the L1 versus L2 issue. Köpke and Nespoulous tested only in L1 and found mixed results with novice interpreters having a statistically superior performance to non-interpreters. They found higher raw scores for the professional interpreters over non-interpreters not to be statistically significant. Liu (2001) only tested in L2 and found no difference between interpreters and non-interpreters. Christoffels et al. tested in both L1 and L2 and found interpreter superiority in both cases.

1.3.6. Task Stimuli

1.3.6.1. Aural Versus Written.

The nature of the stimuli and how they were employed may also account for the inconsistent findings. Recall, there are no consistent patterns that emerged as the result of the use of a particular stimulus form (i.e., written versus spoken) or stimulus type (e.g., words versus digits versus phrases). Table A displays the studies according to nature and manner of presentation of the stimuli along with general results. Printed stimuli, at times, yielded no significant group differences between PSIs and NIMs. This is seen in the Chincotta and Underwood (1998) study with printed digits in both normal and AS conditions and in Padilla et al. (1995) with printed words in normal conditions. At other times, printed stimuli did reveal group differences whereby PSI did significantly better than non-PSI groups. This is seen in Padilla et al. with printed words under AS and with printed phrases under normal, non-AS conditions.

Spoken stimuli showed a similar inconsistency to that of print stimuli. Spoken digits from the Padilla et al. (1995) study revealed significant group differences wherein PSIs performed significantly better than NIMs. Spoken words resulted in mixed findings for Köpke & Nespoulous (2006). Results from spoken phrases were also mixed for Köpke & Nespoulous. Liu (2001) found, however, that spoken phrases did not yield significant group differences. Liu found that the higher raw scores for PSIs over NIMs did not reach statistical significance.

The nature of the stimuli may account for the performance parity among the participant groups in the Köpke & Nespoulous (2006) study. Their attempts to separate phonological from semantic WM may have been undermined by using auditory stimuli. The use of semantic and phonological stimuli in separate conditions is so that one condition invokes semantic processing primarily and the other phonological processing primarily. This way semantic memory and phonological memory can be assessed as independently as possible in order to identify the locus of group performance differences. Auditory stimuli automatically engage the phonological loop and phonological processing. This would make the semantic condition have a stronger phonological processing component relative to the phonological condition's semantic component and render the tasks unequal in their relative processing demands potentially camouflaging differences in semantic versus phonological processing among different participant groups.

1.3.6.2. Semantic Weight.

The nature of word-list stimuli in regard to their semantic characteristics, and consequential semantic or other cognitive processing outside WM, should also be considered when attempting to account for varied findings in the literature. This is particularly important, for example, for the contradiction within the Padilla et al. (1995) study (i.e., significantly longer spans for PSIs than NIMs with words but not digits). Stronger semantic relations among word stimuli that belong to a large open set of options, relative to digits that come from a small closed set of options, may have also contributed to the disparity.

Moreover, word stimuli would have a greater number of semantic associations to facilitate recall relative to digits and non-words. The literature shows that in incidental or delayed recall, such as the free-recall used in the Padilla et al. (1995) study, information is better recalled where salient semantic connections can be made relative to where few to no overt connections exist (e.g., Kroll & Stewart, 1994). This may explain, for example, why no group differences manifested with the word stimuli in the Padilla et al. study. That is, recall for the NIM groups under normal conditions may have been facilitated by semantic connections that, in turn, resulted in a performance on a par with that of the PSIs in the normal condition. The contribution from the semantic associations and consequential long-term memory support may have served a compensatory function and camouflaged a relative weakness in WM for the NIMs compared to the PSI group, should such a WM weakness exist. This support from semantic information may not have persisted in the suppression condition where we saw a stronger WM performance in the PSI group relative to that in the NIMs.

1.3.7. Methodological Variation

Procedural differences may also account for the discrepant findings across groups. The free- and final-recall tasks of the Padilla et al. (1995) study, because of the delayed nature of recall, do not depend as heavily on phonological information or WM as the immediate repetition involved in span tasks. This procedural difference resulting in the activation of other non-WM processes, therefore, may account for the discrepancy within the Padilla et al. study whereby a significant group difference was obtained in immediate unsuppressed recall of digits but not in delayed unsuppressed recall of words. Similarly, time delay may also account for the difference in the free recall findings between Padilla et al. (1995) who presented lists of 16 words and Köpke & Nespoulous (2006) who presented lists of only 12 words.

Köpke & Nespoulous (2007) have also suggested that differences in administration and scoring may account for discrepancies in the literature. They noted, for example, that in sentence span tasks, Liu (2001) compared participant performance on mean list length scores. Christoffels et al., however, compared performance on the mean number of words recalled across the entire experimental set. Administration differences they noted may have influenced the varied outcomes across the literature, but the studies are not sufficiently detailed to make solid conclusions.

1.3.8. Summary

In summary, a variety of factors including small group sizes, group heterogeneity, the varied nature of stimuli, the varied nature of stimulus presentation across studies, and the varied ages of the participants may account for the discrepancy regarding whether or not PSIs have better WM skills than NIMs.

1.4. How to Resolve the Question

Keeping the aforementioned factors in mind, the present study explored three dimensions of WM in an attempt to determine whether or not interpreters have better WM than non-interpreters. First, we made a distinction between storage-only and storage-plus-processing in WM tasks. Simple storage tasks, like cued recall, measure the ability to maintain a limited amount of information in an activated state. In cued recall, an individual is presented with a list of words followed by a cue that prompts recall one of the words in the stimulus list. More complex storage-plus-processing tasks, like reading span, measure an individual's ability to re-activate recently processed information after a brief period of interference. In reading-span tasks, an individual reads a set of sentences and then recalls the last word from each sentence. Second, we acknowledged that within storage-only WM functions, phonological and semantic components must be differentiated. Third, we recognized that lexical-semantic contributions should be minimized to best assess the phonological component of WM. This can be accomplished via a non-word repetition task. In non-word repetition an individual repeats word-like sound strings that have no meaning. Thus their ability to recall strings relies entirely on remembering the phonological shapes of the items.

In attempting to uncover performance differences between PSIs and NIMs, the effects of experimental factors within tasks indicate differences in WM contribution that should also be considered. Such factors include phonological loop functions such as subvocal articulation. They also include commonly reported phonologically-linked phenomena of WM such as length effects, where smaller amounts of information are better remembered than larger amounts (e.g., shorter versus longer words and shorter versus longer word lists), and serial position effects (e.g., primacy and recency), where information presented at the beginning or end of a list is better remembered than information that is situated medially in a list.

Specifically the following questions were addressed:

-Do PSIs have better sub-vocal articulation skills than NIMs?;

-Do PSIs have better non-word repetition skills than NIMs?;

-Do PSIs have better cued recall for phonological and conceptual information than NIMs?;

-Do PSIs have greater reading spans than NIMs?;

-Provided that group differences exist, how much does semantic versus phonological WM and the various dimensions of WM contribute to those differences?;

-Provided that group differences exist, how much does age contribute to those differences?

2. Methods

2.1 Participants: General information

The participants for the study included 47 multilingual adults who were selected for one of four groups that included 13 older interpreters ranging in age from 46 to 67 with a mean age of 56.3 (SD = 7.7), 11 older non-interpreters ranging in age from 48 to 81 with a mean age of 63.6 (SD = 11.6), 12 younger interpreters ranging in age from 30 to 40 years with a mean age of 34.5 (SD = 3.5), and 11 younger non-interpreters ranging in age from 26 to 41 years with a mean age of 31.8 (SD = 5.0). Univariate analyses of variance indicated that the older groups were significantly older than the younger groups (p = .000) and that there were no statistical differences between the ages of younger interpreters and those of non-interpreters (p = .15) and the older interpreters and non-interpreters (p = .09). Extensive background history data were collected according to the questionnaire in Appendix I and, as stated are located in Table C. The questionnaire was generated by the primary investigator of this project based on those used by Goral (2001) and Levy (2004).

All participants had normal language and cognitive functioning as reported themselves and informally judged by the primary investigator who is a speech-language pathologist. The participants also had normal hearing abilities as tested during the experiment. The participants reported to having normal vision or normal vision when corrected with glasses. Comparable education levels were reported across the participants with the exception of OI9, who had no formal education post high school. Other information regarding handedness, and gender can be found in Table C.

The interpreters had all been working in the field for more than one year and all but two had had formal training. Older interpreter nine and OI7 were exceptions in that they were self-taught interpreters. Please see Table C for other information regarding passive and active languages, years working as an interpreter, and amount of simultaneous versus consecutive work.

All but four of the participants, interpreters and non-interpreters, had spent at least one year in an English-speaking country. These four participants were OI13, YI13, YI14, and YI17. All participants reported themselves to be highly proficient speakers of English as a second (or secondarily acquired) language and judged as such informally by the experimenter. Please note that the term *second language* (*L2*) in this study may apply to a literal second language (preceded by only the mother tongue) or a language that follows the first but may have other languages that also precede it and thus be considered a secondarily acquired language. The groups, on average, began learning English at comparable ages as well. The older interpreters had a mean age of acquisition for English (AOE) of 9.7 years (SD = 3.7), the older non-interpreters had a mean AOE of 11.8 (SD = 3.0), the younger interpreters had a mean AOE of 10.0 (SD = 4.9), and the younger non-interpreters had a mean AOE of 7.5 (SD = 4.9). The AOE across groups did not differ statistically. Univariate analyses of variance indicated that the age and the profession groups did not differ regarding when they began learning English (p values of .67 and .06 respectively.)

Each participant rated his or her English skills on a scale from 1 to 7. Only the endpoints of the scale were defined (a score of "1" indicated that an individual had limited knowledge of a given language and a score of '7' indicated having native-like knowledge in a given language). Participants rated themselves on five different parameters: overall skill, speaking ability, listening comprehension, reading comprehension and writing comprehension. The groups were all comparable in their estimation of their language skills in English. Older interpreters gave themselves an average overall score of 6.3 (SD = 0.7). Older non-interpreters gave themselves an average overall rating of 6.3 (SD = 0.6). Younger interpreters gave themselves an average overall rating of 5.8 (SD = 0.7). Younger non-interpreters gave themselves an average overall rating of 6.3 (SD = 0.5). The English proficiency overall rating scores across groups did not differ statistically. The P values were .271 for the Age group comparison, .344 for the Profession comparison, and .221 for the Age x Profession interaction.

2.2 Procedures: General protocol

Testing usually took place over a single two- to two-and-a-half-hour experimental session at the CUNY Graduate Center in New York or the University of Geneva's School of Translation and Interpretation Studies in Switzerland. Two participants, however, performed the experiment across two sessions. One of these participants, YI7, had timing constraints that called for two shorter sessions. His data were not included in the analysis as mentioned above, however, as he did not meet performance criteria. The other participant, YI8, after the practice and first three trials of cued recall, had to stop because of general fatigue from her busy day. She was rescheduled a month later and the testing process began from the beginning (i.e., pre-reading phase, followed by practice, and then the actual task). Only her data from the second testing session were included in the analysis.[1]

Most participants (i.e., 31/47) engaged in four experimental tasks that were presented in the same order to all participants. However, the articulation rate, non-word repetition and reading-span tasks were all added at different points in the data collection process. As a result not all participants participated in all four tasks. Table D indicates which participants performed which tasks. The order of task presentation, however, always followed the same format. After obtaining informed consent, the session began with an articulation rate measure followed by the cued recall task. The conditions within the cued recall task (i.e., phonological-order and semantic-category) were counter-balanced across participants, however, to avoid order effects. The audiological screen followed which, in turn, was followed by the non-word repetition task, and then the reading-span task for the participants who did them. The session ended with a review of the background questionnaire that participants had filled out prior to attending the experiment.

2.3 Articulation Rate

2.3.1. Participants

Thirty three participants took part in the English articulation-rate task. This included 11 younger interpreters, six younger non-interpreters, seven older interpreters, and nine older non-interpreters. The younger interpreter group and the older non-interpreter group each had an outlier who performed more than 2 standard deviations below their group mean. The outliers were YI13 and ON11. The articulation rate data for these participants were not included in the analysis.

2.3.2. Procedures

Participants counted from one to ten, three times in a row as quickly and as accurately as possible. The output was recorded and fed into a software program called Cool Edit Pro. Duration measurements were made from spectrograms of the output by placing one cursor at the first striation indicating the onset vocal-fold vibration in the production of the first number, “one”. The second cursor was placed at the last striation marking vocal fold vibration of the last number, “ten”. The computer calculated the time between the two cursors indicating the time spent articulating. This time spent articulating was considered to be the participants’ articulation rate.

2.3.3. Data Analysis

All but nine of the 33 participants who participated in the articulation-rate task generated the stimulus string on the first attempt. The nine other participants interrupted their speech productions with laughter, omitted numerals, or counted at a normal/slow and not quick rate. In these cases the participants were asked again to count as quickly and as accurately as possible. A second and sometimes third attempt was necessary to collect a complete measurable sample for this subset of participants. The participants and number of attempts at generating the successful speech sample are indicated in the data Table F1. The score used in the analyses was the individual's first attempt that fit all the task-execution criteria.

A second rater was brought in to obtain measurement reliability. One participant from each group (12.5% of the total sample) was selected randomly to measure inter-rater reliability. Measurements across raters were considered to be the same that were within +/- 20 milliseconds of each other. Reliability across the raters was at 100% with this criterion.

2.4. Nonword Repetition

2.4.1 Participants

Thirty nine participants engaged in the Comprehensive Test of Phonological Processing (CTOPP) nonword repetition sub-test. This included 11 younger interpreters, eight younger non-interpreters, 11 older interpreters, and nine older non-interpreters.

2.4.2. Stimuli and Procedures

The nonword repetition subtest consists of 18 nonwords that range in length from one to seven syllables professionally recorded by a female speaker (see Appendix II). The stimuli were presented one a time over headphones at a comfortable hearing level. The task began with three practice items followed by the 18 experimental items. Participants repeated the nonword after hearing it. Responses were recorded for off-line analysis.[2]

2.4.3. Data Analysis

A strict scoring protocol was set whereby all aspects of the non-words were to be matched in production so that each vowel and consonant was produced exactly like the model. No allowances were made for regional English or foreign accents. Any aspiration (i.e., release of air) exaggerated relative to the target, present at the end of a production, even if present with a neutral schwa or schwa-like vowel (e.g., "uh") was acceptable, however.

2.4.4. Inter-rater Reliability

All utterances were scored by the experimenter (the primary rater). A subset was scored by four secondary-raters. All raters had extensive experience with speech-sound analysis as they were clinical speech-language pathologists and/or researchers in neurolinguistics or speech science. The first secondary-rater (rater two) listened to a subset consisting of nine of the participants selected across the four groups. Two criterion measures were applied to this first round of inter-rater reliability scoring. One was strict, not allowing for foreign or regional accent, and accepted responses as correct only if they precisely replicated the target. The other was lenient, accepting responses as correct allowing for common foreign-accent productions of English. Inter-rater reliability was at 82% according to the strict criterion and at 93% with the lenient criterion measure between the primary rater and rater two.

Once the primary rater scored the full data set, a number of productions remained ambiguous so that a score of correct or incorrect could not be easily applied to a participant's production. Another secondary rater (rater three) was called in to judge these productions because of the limited availability of rater two. The subset rater three judged included a total of 102 non-words across 31 participants. Rater three, however, also found a number of the productions difficult to apply a score of correct or incorrect to. As a result a new subset was generated for another secondary rater (rater four).

The subset for rater four were the 36 productions that included tokens that rater three could not disambiguate (i.e., give a score) and tokens that did not have a consensus across the raters following comparison to the scores applied by the primary rater or rater two. Where raters disagreed, an originally ambiguous production was given the score that had the highest consensus among raters. A production received the score of the consensus of raters, so that if two raters gave a production a "0" and one rater gave the same production a "1" the official score for that production would be "0". The subset for rater four included 36 words across 24 participants. The primary rater and rater three also re-listened to the productions they deemed as ambiguous and successfully applied a score to each.

Comparing the scores across raters one through four, once raters one and three applied scores to all the productions successfully all but one production had a consensus score. This particular score was evenly split across the four raters. Again, due to the availability of the previous raters, a fifth rater was called in to make the tie-breaking decision on this production. The inter-rater reliability for raters one and three was 78%. Inter-rater reliability between rater one and rater four was 65%. Inter-rater reliability for reliability for rater-one and rater-five was 100%.

These arguably low inter-rater scores between rater one with raters three and four were deemed acceptable because of the high degree of inter-rater reliability between raters one and two who analyzed both ambiguous and straightforward productions. The corpus that raters four and five analyzed included only particularly problematic and ambiguous stimuli. Thus, the relatively low inter-rate reliability would not be surprising because this problematic stimulus subset was difficult to score because of the very subtle acoustic differences that exist in sound production. The only difference, for example, between the production of a “p” and ‘b’ sound is about 50 milliseconds (Borden, Harris, and Rafael, 1994) of vocal fold vibration. The boundaries that demarcate whether or not a sound is a ‘p’ or a ‘b’ sound can overlap, especially with foreign-language speakers. If this sound is critical to determining whether or not a word (or non-word) is produced correctly, great difficulty assigning correctness can result. This was particularly so in this rating task since there is no linguistic context with non-words to help the listener determine what the speaker intended.

2.5. Cued Recall

2.5.1. Participants

The participants for the cued recall task included 46 of the 47 participants as described in the Participants: General information section above and displayed in Table D.[3]

2.5.2. Stimuli

The stimuli for this experiment were modified from Carter and Haarmann (2001) and were used for both a semantic-category and a phonological-order condition (see Appendix III).[4] The stimulus lists include 96 lowercase printed words that belong to six semantic categories (e.g., animals, food, nature). The words are matched for their frequency of occurrence according to Kucera and Francis (1967) and for concreteness, familiarity and imageability characteristics according to Coltheart (1981). Matching the stimuli in this way ensured comparable recall potential across the corpus. The stimuli are comprised of either short (one to two syllables) or long (three to five syllables) words to test for word-length affects (i.e. better recall of shorter than longer words) particular to the phonological loop of working memory. The corpus was pseudo-randomly and repeatedly distributed into trial lists of six words in length with each word belonging to a different semantic category, no repeated words within a list, and no words beginning with the same phoneme within a list.[5]

2.5.3. Procedures

A cued recall paradigm, adopted from Haarmann and Usher (2001), allowed for relatively independent assessment of semantic versus phonological WM. Task procedures were designed to dissociate WM from long-term memory and semantic from phonological WM as much as possible. The task began with an oral pre-reading phase. Participants saw the stimulus lists grouped by semantic category. They then read through the entire stimulus set twice while thinking about how each word fit into its category as defined in the experiment.

In the experimental task participants saw lists of lower case words, presented one at a time, on a computer screen at a rate of one word every second. The last stimulus word in a trial list was immediately followed by a cue word in capital letters and a question mark (e.g., FRUIT?). The cue word in the phonological-order condition was one of the words from the present stimulus list and referred to the position of an item in the stimulus list. Participants were asked to recall the word in the list that occurred immediately after the cue word. For example, given the trial list, “apple, miner, wolf, dew, ache, flute” and the cue, “APPLE?”, participants should recall the word “miner” because “miner” follow “apple” in the stimulus list. The cue, “FIRST?” prompted recall of words in list-initial position. The cue word in the semantic category condition was the label of the semantic category to which one of the words from the trial lists belonged. For example, the participant may have seen the words, “apple, miner, wolf, dew, ache, flute” and the cue, “FOOD?” participants should recall the word, “apple” because an apple is a type of food item. All positions were prompted for recall six times for a total of 72 trials per condition of the experiment.[6]

2.5.4. Data Analysis

A mean performance was calculated for each participant for each position in both the phonological-order and semantic-category conditions. The scores were entered as data points in a series of mixed-factor ANOVAs. Between-subjects factors included age (younger, older) and profession (interpreter, non-interpreter). Within-subjects factors included word length (short, long) and serial position (1-6). Interactions were analyzed with post-hoc Tukey tests.

2.6. Reading Span

2.6.1. Participants

Thirty eight participants part took in the reading-span task. This included twelve younger interpreters, eight younger non-interpreters, seven older interpreters, and eleven older non-interpreters. Table D profiles which participants were given this task and thus included in the data analysis. Graph RRS1 displays the group data as well. Of the 38 participants in the reading-span task, two had scores that qualified them as outliers. Participants YI8 and OI9 had scores that were 2 standard deviations or more below the means for their respective groups. These participants' data were removed for group analysis.

2.6.2. Stimuli

This task is a direct replication of Ingrid Christoffels's (2004) English reading-span task. The stimuli in this reading-span task were those used by Christoffels. Christoffels created 42 English sentences, 11 to 13 words in length, that were partly derived from those used in Harrington and Sawyer (1992). The final words across the sentences were carefully selected to be balanced for length and frequency and not to rhyme. Two additional practice sentences were generated for this experiment, however, that were not used in the Christoffels study. Christoffels provided only two practice sentences when sharing her stimulus set but used two sets of two sentences in her practice phase of the experiment. The stimuli were organized into three sets of two to five sentences. Stimulus presentation was incremental in that first three sets of two sentences were presented followed by three sets of three sentences, and so on up to three sets of five sentences. The stimuli can be found in Appendix IV.

2.6.3. Procedures

The sentences were presented one at a time on a computer screen. Each sentence was preceded by a warning tone occurring with a blank screen for 500 ms. The participants then read the sentence aloud at a normal pace. Once a sentence was read, the experimenter triggered the next sentence by hitting a key on the computer's keyboard. Following the last sentence in a set, the screen read, "*****Please recall the final words*****", to prompt the participant to recall all the final words from the set in any order. The task began with two practice sets of two sentences, followed by the 42 experimental stimuli arranged into three sets of two, three, four, and five sentences. The experimenter scored the task on-line, but recorded the session as well for back-up.

2.6.4. Data Analysis

Participants received credit (a score of one) for every word recalled correctly for a possible total raw score of 42. Performance raw scores were converted to percentages for analysis. Absolute values could not be used in data analysis because trials had to be eliminated from participants OI6 and YN9. Each of these participants began recalling final words aloud when they should have been reading another sentence. This occurred for participant OI6 in a four-sentence set and for YN9 in a three-sentence set. Thus, their percentages were calculated from sets of 38 and 39 words respectively. Data from the reading-span task were analyzed with descriptive statistics and a univariate ANOVA.

3. Results

Tables E and F show the correlations among the four tasks and the descriptive statistics for each individual task respectively. There was a significant relationship between the two cued recall conditions ($r = .780$, $p < .01$, $n = 44$). There were no other significant correlations, however.

3.1 Articulation Rate

Table F1 and Figure 2 display, respectively, the individual performances of the participants who took part in the articulation-rate task as well as combined group scores. A Two-Factor Univariate ANOVA was conducted to examine performance on the articulation rate measure. Fixed factors included Age (younger, older) and Profession (interpreter, non-interpreter). No effects were significant. The interpreter group achieved higher raw scores, consistent with the literature. The p value, however, did not approach significance ($p = .29$).

3.2. Nonword Repetition

Table F2 and Figure 3 profile, respectively, the individual performances of the participants who took part in this task as well as collective group scores. A Two-Factor

Univariate ANOVA was conducted to examine performance on the non-word repetition task. Fixed factors included Age (younger, older) and Profession (interpreter, non-interpreter). A main effect of Profession was revealed [$F(1,32) = 7.069$, $p = .012$, $MSe = 1057.24$]. There were no other significant effects, though it is worth noting there was a trend for an Age by Profession interaction ($p = .089$).

The main effect of Profession was due to the better performance of the interpreters. The younger and older interpreters recalled 10.89 and 8.5 non-words respectively on average. The younger and older non-interpreters recalled 8.14 and 8.4 non-words respectively on average.

3.3. Cued Recall

Forty-six volunteers were run successfully on the cued recall task. Individual data can be seen in Table F3. A small number of trials were eliminated from data analysis, however, in instances when the participant did not know the word targeted for recall (i.e., they had not heard of the word in English), as determined in their post-testing report. Appendix V displays the words and trials removed from data analysis for each participant. No participants had more than five percent of their trials discarded from data analysis. The need to remove some trials from data analysis was not uncommon, particularly for the younger participants, as the participants were all performing in a second language. As a result, percentage correct was calculated for each position and used for data analysis.

3.3.1. Phonological-Order

A Repeated Factors ANOVA was conducted to examine performance in the phonological-order condition. Between-subjects factors included Age (younger, older) and Profession (interpreter, non-interpreter). Within-subjects factors included Word-length and Serial position (one through six). Main effects of Word-length [$F(1, 40) = 63.39$, $p < .001$, $MSe = 31{,}889$] and Serial position [$F(5,200) = 21.93$, $p < .001$, $MSe = 14{,}785$] manifested. There were no significant main effects of Profession or Age. Interactions included Word-length by Serial position [$F(5,200) = 2.58$, $p = .028$, $MSe = 935$] and Age by Serial position [$F(5,200) = 2.89$, $p = .015$, $MSe = 1{,}948$].

The Word-length main effect indicated better recall of shorter relative to longer words. The main effect of Serial position revealed primacy and recency effects whereby words from positions one and six were recalled significantly better than words from all medial positions. None of the medial positions, positions two through five, were significantly different from one another.

The Word-length (WL) by Serial position (SP) interaction (Figure 4) was due to the presence of a Word-length effect in the earlier positions (i.e., one, two, and three), but not the later positions (four, five, and six). Analysis of this WL x SP interaction also indicated short-word lists evidenced primacy and recency effects whereby the number of words from position one and six were recalled better than words from all medial positions. None of the medial positions 2 through 5 were significantly different from one another, however. The analyses also revealed a steeper primacy effect for the long-word lists relative to the short-word lists. Word recall from positions one and six of the long-word lists was significantly better than all medial positions. Additionally, unlike the short-word lists, the medial positions all significantly different from one another except for positions two versus four, two versus five and four versus five. Figure 4, depicts the long-list heightened steepness. The short- and long-list lines run relatively parallel with the exception of position three, where performance on the long-list drops significantly.

The interaction between Age and Serial position (Figure 5) was due to the presence of both recency and primacy effects for the older participants, only primacy effects for the younger participants. There was no recency effect for the younger participants ($p = .642$)

The older group also exhibited a significantly steeper primacy effect relative to the younger participants which also contributed to the presence of the interaction. The significance was tested by calculating the differences in performance between recall in position one and position three for both the short and long words. A repeated measures ANOVA was run using Age and Profession as between subjects variables and Word-length as within subjects variable. The results revealed a main effect of Age [$F(1, 40) = 139.60$, $p = .039$, $MSe = 92371.01$].

Relative to the younger group the older group also showed a strong recency effect recalling significantly more words at position six relative to all other positions save position one. The younger group demonstrated no significant difference in the recall of words in the final position relative to any of the others.

In summary, recall of words in the phonological-order conditions yielded Word-length effects for words in positions one, two and three in the serial list. There was no difference in recall of short and long words, however, in the later positions four, five, and six. We also see that word-length affected the degree of serial position effect that manifested. Short-word lists evidenced a shallower serial position curve relative to the long-word lists. Age differences also manifested in the phonological-order condition; older participants evidenced both primacy and recency effects while younger participants demonstrated only a primacy effect. The primacy effect was also steeper for the older adults relative to the younger adults. No differences between Professional groups were noted.

3.3.2. Semantic-Category

Another Repeated Factors ANOVA was conducted to examine performance on the semantic-category task. As in the phonological-order condition the between subjects factors included Age (younger, older) and Profession (interpreter, non-interpreter). Within-subjects factors included Word-length and Serial position (one through six). Main effects of Word-length [$F(1, 40)$ 11.65, $p = .0015$, MSe = 3,794] and Serial position [F $(5,200) = 35.88$, $p < .001$, Mse = 18,712] manifested. One two-way interaction of Word-length by Serial position [F (5,200) = 5.33, p = .00012, MSe = 1,539] was noted. No main effect of Age or Profession emerged, however.

The Word-length main effect was due to better recall of shorter than longer words. The main effect of Serial position was a result of recency effects whereby word recall was best at position six and progressively worse to a significant degree moving back through positions five, four and three. Positions three through one had the poorest recall and were not significantly different among each other.

The Word-length by Serial position interaction (Figure 6) was due to a somewhat steeper recency curve for the long words relative to the short words. Neither word length evidenced primacy effects. The interaction analysis also revealed that more short relative to long words were recalled correctly at position five. There were no differences in the recall of short versus long words at any other position, however.

In summary, the semantic-category condition evidenced a small Word-length effect. Participants recalled short words better than long words only when the occurred in serial position five. Performance on this condition revealed only recency, no primacy effects. The recency effects were steeper for the longer words relative to the shorter words. No differences in Age or Profession were noted.

3.3.3. Task Effects

A repeated factors ANOVA was run to assess the prediction of greater Word-length and Serial-position effects in the phonological-order relative to the semantic-category recall. Age (younger, older) and Profession (interpreter, non-interpreter) were entered as between subjects factors and Word-length (short, long), task (phonological-order, semantic-category), and Serial position (1-6) as within subjects factors. Only the results involving task-type are reported here, as the other significant effects are reported in the sections above. The results, however, should be interpreted with caution since, despite attempts to equate the tasks as much as possible, the two conditions are not necessarily equal in their processing demands.

This analysis revealed a main effect of Task type [$F(1,40) = 114.78$, $p < 0$, Mse = 86344.53] and interactions of Task by Word-length [$F(1,40) = 20.73$, $p < .001$, Mse = 6842.38], Task by Serial position [$F(5, 200) = 19.09$, $p < .001$, Mse = 9183.30] and Task by Word-length by Age [$F(1,40) = 5.20$, $p = .028$, Mse = 1715.95]. There were no significant main effects for the between subjects factors (though there was a trend noted for an interaction of Age by Profession ($p = .072$)).

The main effect of Task indicated better recall of words in the semantic-category condition than in the phonological-order condition. The interaction involving Task-type by Word-length by Age (Figure 7) was indicated by a word-length effect for the older participants in the semantic-category task, despite not being revealed in the previous analysis that only factored in the semantic condition data. The older participants recalled significantly fewer long words relative to short words in the semantic-category condition. The younger participants, in contrast, evidenced no difference in recall of long and short words in this condition. Both groups, however, did show word-length effects in the phonological condition.

The interaction of Task-type by Serial position (Figure 8) indicated the presence of both recency and primacy effects in the phonological condition whereby primacy was indicated with greater recall in position one relative to all positions except position six. Recency was similarly indicated with greater recall at position six relative to all other positions except position one. In contrast the interaction indicated the presence of only recency effects in the semantic condition with greater recall at position six relative to all other positions with recall from the first position being the poorest.

In summary, overall recall was better in the semantic relative to the phonological condition. The phonological condition revealed both recency and primacy effects in contrast to only recency effects in the semantic condition. Word-length effects manifested whereby short words were recalled better than long words within and across conditions. Age differences manifested, as well, regarding Word-length. Although all participants evidenced word-length effects in the phonological condition, only older participants demonstrated such effects in the semantic condition.

3.3.4. Cued Recall Summary

Overall best performance was seen in recall of information that was cued via semantic-category information relative to phonological-order information. Shorter words were also recalled better relative to longer words. Although no difference of Profession manifested, there was a trend in this direction that merits further empirical and/or meta-statistical investigation. Age differences appeared, independent of profession, that were sensitive to context (semantic versus phonological), Serial position, and Word-length. Older participants evidenced both primacy and recency effects in the phonological condition of this task while younger participants demonstrated only primacy effects. The older participants also evidenced word-length effects in the semantic condition though the younger participants did not.

3.4. Reading Span

Table F4 and Figure 9, respectively, profile the volunteers who participated in this task as well as individual and group scores. A two-factor univariate ANOVA was conducted to examine performance on the reading-span task. Fixed factors included Age (younger, older) and Profession (interpreter, non-interpreter). A main effect of Profession [$F(1, 32) = 4.98$, $p = .033$, $MSe = .022$], was revealed. No other effects were significant. Interpreters outperformed non-interpreters. The younger and older interpreters had average performance scores of 87.2 and 84.5 respectively. The younger and older non-interpreters had average performance scores of 81.4 and 80.0 respectively. Despite the propensity for younger participants in each profession group to have higher mean performance scores, there was no Age x Profession interaction ($p = .79$).

3.5 Summary of Experimental Findings

Regarding profession, advantages for interpreters were noted in non-word repetition and reading span. These are, interestingly, two tasks akin to processes simultaneous interpreters engage in (i.e., hearing and repeating new words and listening to sentences and then responding). No differences across profession groups were noted in articulation rate for English digits or cued recall.

Differences regarding age manifested in a different pattern relative to profession. No age differences were noted in non-word repetition, reading span or articulation rate. There were differences, however, in the recall patterns in cued recall between younger and older participants in that older participants showed greater phonological loop and serial position effects. The overall percent of recall was not significantly different, however, between the age groups.

4. Discussion

This study sought to determine whether or not professional simultaneous interpreters have better working memory skills than non-interpreter multilinguals and whether or not age plays a role in performance differences. Consistent with the literature regarding cognitive processes in simultaneous interpreters, the study yielded varying results. The present study, being broad in scope for working memory components, however, provides novel information to help better understand how these two populations differ. Generally, the findings here suggest that superior working memory functioning for interpreters is independent of age and depends on the nature of the memory task. Similarly, age differences are independent of profession and also vary depending on what aspects of memory are in process.

4.1. Interpreters Versus Non-interpreters

The nature of a working memory task and its underlying cognitive processes seem to play a role in whether or not interpreters outperform non-interpreters to a statistically significant degree. Interpreters repeated non-words more accurately, suggesting they have better phonological storage, and they achieved higher reading-span task scores, suggesting they have better complex-storage-and processing skills. By contrast, at first inspection, the profession groups performed similarly in articulation rate, suggesting they have comparable sub-vocal rehearsal skills and in cued recall suggesting similar storage and rehearsal for lists. As will be discussed below, however, there may be more differences between groups than the data overtly demonstrate.

4.1.1. Rehearsal

Let us first consider the most basic component of working memory among the given tasks, sub-vocal rehearsal as assessed via articulation rate. There were no group differences in articulation rate, suggesting that the groups did not differ on phonological-loop rehearsal skills. Thus, it is logical to suggest that all groups are able to refresh information in working memory comparably on this fundamental level. This is not a surprising finding as interpreters don't have time to subvocally rehearse a message they are interpreting. Thus, subvocal rehearsal is not a working memory subskill that would be honed as a result of the training in and practice of simultaneous interpreting. Also supporting the idea of comparable rehearsal skills for PSIs and NIMs are the findings from the phonological cued recall task which relies on phonological rehearsal where no differences manifested between interpreters and non-interpreters.

These null findings, of course, do not necessarily indicate that there are no group differences, however. Sub-vocal rehearsal skill difference between interpreters and non-interpreters still merits further investigation. Recall that interpreters achieved higher raw scores than non-interpreters producing faster rates of articulation and recalling more cued words. A larger group of participants may reveal significant differences in these tasks. In addition, in the case of articulation rate, the overt articulation of numbers, because of their phonetic simplicity and high degree of familiarity, may not be sufficiently sensitive to group differences in this subskill. The use of less predictable, less practiced words or even non-words may be a better gauge of rehearsal ability since, in being diverse; they are more akin to what is processed in real-life communication situations and thus more representative of actual ability.

4.1.2. Storage

There were two storage-related tasks in the experiment: the non-word repetition task where interpreters were advantaged and the cued recall where the groups performed on par. Although these were both storage related, they were quite different in the cognitive processes they entailed. Consider first the non-word repetition task, the less complex of the two storage related tasks.

Interpreters may be at an advantage for non-word repetition because two aspects of their job invoke phonological-loop processing. The first is that since interpreters need to be highly familiar with the lexical jargon of the topic on which they interpret, they are often learning new vocabulary (i.e., akin to novel words) as a regular part of their job as they accept new assignments. Phonological-loop functioning, which includes storage, is associated with vocabulary learning (e.g., Gathercole and Baddeley, 1989). This increased practice with phonological-loop storage function may give interpreters an advantage in a storage task such as non-word repetition. Increased vocabulary knowledge may also add to the overall long-term knowledge of lexical sound structures, which helps support information in working memory, especially non-word repetition and learning. We know, for example, that trilingual speakers perform better on non-word repetition and learning tasks than bilinguals and that bilinguals perform better on these tasks than monolinguals (Papagano and Vallar, 1995). This suggests that interpreter/non-interpreter differences may be higher up the cognitive chain than working memory.

The second aspect of their vocation that may give interpreters an advantage is that they are often repeating novel proper names of the participants of the meetings for which they interpret. Proper names, especially across languages and cultures, are also analogous to non-words. Thus, interpreters may simply have more practice at this task and/or better development of the underlying cognitive functions that support such a task gives them an advantage over non-interpreters. This, of course, would include processes such as phonetic encoding and neuro-motor production.

A third explanation to consider regarding why interpreters outperformed non-interpreters in non-word repetition is the phonetic aspect of this task as just mentioned. It could be that the difference between interpreters and non-interpreters in non-word repetition is not in, or not only in, storage. Performance differences could manifest during the phonological encoding of the motor patterns for generating speech, especially for novel speech. This, again, also raises the related question of the appropriateness of assessing articulation rate by using number-words which are very simple phonetically, highly rote, and quite automatic. It is not surprising that among motorically intact adult speakers that no group differences would manifest with digit stimuli. The answers to both of these questions are outside the scope of this paper, but are worth considering in future research.

A word of caution regarding the suggested findings of better interpreter performance in non-word repetition over non-interpreters needs to be expressed. Although attempts were made to control for language background and experience, no formalized analysis of degree of foreign accent was conducted. Since no allowance for foreign accent substitutions was permitted in scoring acceptable responses on non-word repetition, more heavily accented speakers would be at a disadvantage relative to less accented speakers.

It is feasible that some might argue that the interpreters may speak English with less of a foreign accent than non-interpreters for two reasons. First, the interpreters had a pattern for earlier age of English acquisition. Second, being language professionals, they may have worked to improve pronunciation more than the non-interpreters. This potential difference would have given them an advantage in the non-word repetition task, as mentioned above. Thus, a more lenient scoring system that permitted known foreign accent substitutions might have yielded on par performance across the groups in non-word repetition.

4.1.3. Phonological Storage Differentiated From Semantic Storage

There was no difference between interpreters and non-interpreters in cued recall, despite the fact that cued recall may be considered to be a storage task like non-word repetition where group differences were found. There are clear differences between these storage-related tasks, however, that may explain this contradiction. Cued recall requires larger amounts of information to be stored for longer duration relative to non-word repetition where storage time is very short. Thus there may be a ceiling effect of sorts for the interpreter advantage in short-term memory storage for words. That is, interpreters may have a storage advantage at the single-word level or when the response is more immediate (which mimics interpreting). At the six-word level (and perhaps a fewer words) this difference drops in statistical significance.

Cued recall also involves an element of processing in the form of the judgment participants must make to associate the cue word with one of the words from the stimulus list. Such a step is not included in non-word repetition. This decision process adds a step to the task that is not involved in non-word repetition and creates additional delay in response that may contribute to the difference in findings across these two storage tasks. It also substantiates the idea that interpreters' superiority is evident when the responses are more immediate. The cued recall results might suggest that interpreters lose their memory advantage above simple storage processing. We see, however, that this is not the case from the reading-span task outcomes which will be addressed next.

4.1.4. Storage-and-Processing

Interpreters out-performed non-interpreters in the complex storage-and-processing task of reading span. Aside from having the highest processing demands relative to the other tasks in this study, the reading-span task, also relative to the other memory tasks involved in this study, is more akin to what interpreters do in their job as interpreters; i.e., process incoming sentence or phrasal information and give a response after a short delay.

Thus, general task familiarity or development of the underlying cognitive functions that support this task may have given interpreters their advantage.

It was proposed earlier that when a response is delayed, interpreters may lose their advantage over non-interpreters as suggested by the differences in non-word repetition (no delay) versus cued recall (varied delay). The reading-span results seem to undermine this argument, however. Again it may be the nature of the task and related delay that account for interpreters outperforming non-interpreters on the reading-span task and not on cued recall. The delay for reading span is markedly longer than for cued recall (i.e., it takes longer to present and read four sentences than it does to read four words). This delay, then, may allow for deeper processing of the information to be recalled which can facilitate recall. Additionally sentence stimuli, relative to unrelated word lists, are logical, provide context, and include more information which can also aid recall. Thus, the greater delay between stimulus presentation and recall, the decreased external demands on processing speed, and the opportunity for deeper processing may be what gave interpreters an advantage in the reading-span task as a result of their work experience. Thus, in terms of underlying cognitive processes, it may be that storage, encoding, decoding, and/or executive functions are the aspects of sentence processing in working memory that give interpreters an edge over non-interpreters.

4.1.5. Summary

Interpreter-non-interpreter differences in working memory performance depend on the nature of the memory task. This includes the amount of information to be processed, type of processing involved (e.g., phonological, semantic, lexical or sentence), and response delay. Looking at performance on the experimental tasks moving from less to the more complex, we recall that there was no apparent advantage for interpreters in the rehearsal of rote phonological information in working memory as seen in the articulation-rate measure. There is a potential interpreter advantage, however, for storage of small amounts of phonological information (i.e., the equivalent of a single-word) that is to be recalled immediately as seen in the non-word repetition results. The interpreter advantage diminished, however, for storage of larger amounts of information, when the information consisted of lists of unrelated word lists, recall is not always immediate, and small amounts of processing were required as was seen in cued recall. When larger amounts of information were organized into sentences, however, interpreters, again, were at an advantage even with considerable delays before responding.

The literature continues to be contradictory regarding the role of phonological storage (and perhaps rehearsal) in simultaneous interpreting and whether or not interpreters are advantaged over non-interpreters in this domain and working memory in general. There is a growing consensus in the literature, however, that the advantages for interpreters over non-interpreters on working memory tasks are domain specific (e.g., Christoffels, 2006, Köpke & Nespoulous, 2006, Liu, 2001; Moser-Mercer, 2000). The results of this study, indicating better non-word repetition and reading span, are consistent with the idea that advantages for interpreters in working memory regard working memory tasks or processes that mimic aspects of their highly practiced professional skill.

4.2. Older Versus Younger Participants

There are not many age differences in the aspects of WM as assessed by the tasks in this experiment. The differences uncovered were mostly qualitative in nature. Recall that older and younger participants were comparable in their ability to refresh phonological information in working memory as assessed by the articulation rate of English digits. In general, they also performed similarly in phonological storage and immediate recall of single words as assessed by non-word repetition. On higher level storage-and-processing, age groups were also found to be similar as assessed via reading-span task performance. However, a number of these findings should be qualified as you will read below.

The absence of age effects among the interpreters on the non-word repetition task should to be interpreted with caution. Recall that there was a marginally significant interaction in this task between age and profession ($p = .089$) suggesting a potentially stronger performance for the younger interpreters over the older interpreters. Considering the small N in this study, it is reasonable to believe that this marginal difference could become significant with more participants. This would then suggest that interpreters do not maintain this advantage across the life span.

The findings for the reading-span task also need to be qualified because the lack of age effect is somewhat surprising. The literature regarding cognitive skills in healthy older individuals typically shows declines in reading span performance relative to younger adults. The wide age-span of the older adults in this study (i.e., 46 to 81 years) could possibly account for lack of age effect. Alternately, the older adults in this study may have been too young for significant effects to emerge.

Language background might also explain the absence of age effects in the reading-span task in the present study. The literature on older adults and reading span decline has involved monolingual speakers (e.g., Miller and Odell, 2007; Federmeirer and Kutas, 2005; Kemper and Sumner, 2001). Our participants, in contrast, were highly proficient multilingual speakers. Superior performance of interpreters over non-interpreters on reading span in this study and in the study by Ingrid Christoffels' (2006) suggests there is something special in the processing skills of highly proficient multilinguals. Work by Ellen Bialystok and colleagues, in particular, has demonstrated enhanced cognitive skills into late adulthood for multilingual relative to monolingual speakers (e.g., Bialystok, 2006, and Bialystok, Craik, Klein, and Viswanathan, 2004).

The present study showed that there were more obvious age differences noted when the task was a storage-based task and involved information above the single-word level such as cued recall. In the cued recall task, qualitative age differences were noted in various aspects of recall depending on the content (phonological or semantic), the length (short or long words), and the serial position (one through six) of the word to be recalled. Quantitative differences, in terms of the percent of words recalled, never reached statistical significance. The younger groups did achieve higher raw scores that with more power could become significant.

4.2.1. Phonological Cued Recall

The older participants experienced greater serial-position effects relative to the younger participants in the phonological-order condition. Recall that the older participants experienced both primacy and recency effects, but the younger participants experienced only primacy effects. The older participants also experienced significantly steeper primacy effects relative to the younger participants. This suggests that older and younger participants may experience different degrees of attention to, interference of, decay of and/or chaining skills which are believed to influence serial position effects (See Oberauer, 2003; Cowan, Saults, Elliott, and Moreno, 2002). Exactly how these possible phenomena account for the serial position effects produced in this study is beyond the scope of this paper. How older and younger participants differ on these sources of serial position effects merits investigation in the future, however.

Additionally, it is also worth noting that, although there was no statistically significant difference in the number of words recalled in this condition overall, there was a tendency for younger participants to achieve higher absolute mean recall scores relative to the older participants in 11 out of 12 serial positions (i.e., six short-word list positions and six long-word lists positions). These findings suggest that the older participants may not be as efficient in processing phonological information as the younger participants.

The results suggest that there may be a modest capacity limitation for the older participants. Recall there was no age differential at the single-word level in the non-word repetition task. This capacity limitation seems to be isolated to storage of unrelated word-lists, above the one-word level, since no age differences manifested in the complex storage-and-processing task of reading span either. It could be that, for the recall of items from unrelated-word lists, older participants are more susceptible to interference or decay of the items that often associated with serial position effects.

4.2.2. Semantic Cued Recall

Unlike in the phonological condition, there were no age-related differences in serial position effects in the semantic-category condition. Instead, the age groups differed in the effects of word-length, in that older participants experienced word-length effects in this task and younger participants did not. This is a somewhat surprising finding in that, being a semantic task, effects of phonological processing such as word-length were expected to be minimal. These results suggest different processing strategies between the two age groups: The older participants are relying on phonological information and phonological processing in this semantic task to a greater degree than the younger participants. Haarmann et al. (2005) show evidence of semantic working memory deficits, as reflected in decreased conceptual span, with increased age but preservation of phonological working memory (i.e., as assessed via digit span). Thus, it is reasonable to suggest that the older participants are relying on phonological strategies to execute this task as a result of decreased semantic working memory skills. Consequently, older participants are evidencing effects of the phonological loop in this semantic task and younger participants are not.

It is worth noting the potential contradiction in phonological-skill ability in older persons reported by Haarmann et al. (2005) and the present study. It is likely that the unmatched complexity and processing demands of digit span, used in the Haarmann study, versus cued recall, used in this study, led to discrepancy in claims regarding aging phonological skills. Cued recall may be a more sensitive measure of phonological skill. It may also be that the participants in the Haarmann study, who ranged in age from 66 to 85, were older on average relative to the participants in the present study, who ranged in age from 48 to 81. It is possible that both phonological and semantic processing skills are declining with age, but semantic skills may decline at a greater rate. As a result there may be times when older participants rely on phonological processing to aid semantic processing. As a result we may find outcomes like word length effects in a semantic task as we did in our cued recall task.

These results in semantic cued recall condition also support the idea of a capacity limitation for the older participants as they are at a greater disadvantage with longer words relative to shorter words whereby the younger participants are not. In addition, analogous to the phonological condition on the cued-recall task, there was a tendency for younger participants to have higher mean scores for the number of words recalled across 8 of the 12 serial positions, despite not reaching statistical significance overall.

4.2.3. Summary

In summary, we see that there are age effects that arise in de-contextualized stimulus processing in working memory. No significant age differences were noted in articulation rate/subvocal rehearsal or reading span. Subtle age effects were noted in phonological processing with regard to unrelated word lists in cued recall in that older participants experienced both recency and primacy effects and younger participants experienced only primacy effects. The use of compensatory phonological strategies in semantic cued recall by the older participants, but not by the younger participants, suggests a decline in semantic processing as well among the elderly.

4.3. Working Memory in Multilinguals

Research shows that individuals who speak more than one language are different from those who speak only one. In particular, their working memory skills have been shown to be different. Thus, since this paper addresses differences in working memory skills, it is important to discuss the results of the multilingual brain as well. In this study we found the expected and traditional working memory phenomena such as recency, primacy, and word-length effects. We also saw better recall of semantic relative to phonological information and had a surprising result of an age as discussed above. We obtained answers to our research questions regarding differences between PSIs and NIMs on the four mentioned tasks and whether or not age played a roll in those differences. The results showed that interpreters were better on the non-word repetition and reading-span tasks and that age does not play a factor in performance differences. These are the answers we found at first glance. When one considers that the participants in this study were all working in a second language, the answers to our questions must be taken cautiously regarding what they say about the overall working memory function of our participant groups. The obvious question that arises is how these groups would perform when functioning in their dominant languages.

The literature on bilingual memory shows that individuals, for the most part, are more efficient at processing a native language than a subsequently acquired language. (e.g., Hahne, 2001; Juffs, 2004; Stowe & Sabourin, 2005). The exception to this native language advantage has been generally limited to digit span tasks when digits in a native language are longer than non-native digits. Recall the Ellis and Hennelly (1980) and the Daró and Fabbro (1994) studies reported in the introduction show that word-length outweighed native language skill for determining best performance in digit-span tasks. It is important to note when considering L1 versus L2 working memory performance that most of the studies in the literature to date have not typically involved professional interpreters. There is evidence to suggest that interpreters may behave differently from non-interpreters in L2 skills.

Few of the working memory studies in the interpreting literature have assessed their participants in both an L1 and an L2. The only studies that did bilingual testing are Christoffels et al. (2006) and Chincotta and Underwood (1998). Chincotta and Underwood (1998) found no differences in L2 performance between their student interpreters and non-interpreters using digits. As discussed earlier, however, digits are not ideal for assessing language skill. Christoffels et al.'s results with reading span, however, revealed equal performance across L1 and L2 for interpreters. Their student and teacher groups, in contrast, both performed better in their L1 in this working memory task. Christoffels et al., also, interestingly, found that professional interpreters performed better in their L2 relative to L1 on their word-span task. By contrast, students and teachers performed better in L1.

The reading-span task conducted in the present experiment was a replication of the English task performed in the Christoffels et al. (2006) study. Thus it serves a good source for estimating L1 performances in the population at hand. Considering this and Christoffels' and colleagues' findings it is reasonable to speculate that the interpreters in this study would also be advantaged in their native languages relative to non-interpreters on the memory tasks where the interpreters excelled. Also supporting this assumption is the convergence hypothesis suggesting that L1 and L2 processing become more similar as proficiency in L2 increases (Birdsong, 2006). Since the interpreters and non-interpreters in this study were comparable in English use and skill, it may be that practice in the very unique language processing involved in interpreting contributed to the group differences.

On par L1/L2 performance is not assumed for interpreters in all memory tasks. As with PSI versus NIM differences, the nature of the task may likely dictate to what degrees and in what ways processing in L1 and L2 differs in memory tasks. As mentioned above, on par performance in L1 would be predicted for the interpreters in this study in the complex-storage and processing task of reading-span task, this is not likely so in the cued recall task which is primarily a storage task.

Perhaps, therefore, it is the storage of unrelated word lists (or storage above one word) where we will find an L1 advantage. We do have indirect evidence that this is the case with cued recall. Recall that the cued recall task from this study was modified from a study by Carter and Haarmann (2001). The Carter and Haarmann (2001) study involved monolingual English-speaking university students ages 18 to 30 years. The results comparing the participants from the present study and the Carter and Haarmann study can be found in Table G. The comparison should be interpreted with caution since two notable changes were made for the present study. The first is that the stimulus list from Carter and Haarmann was rearranged so that no individual stimulus list contained two words with the same initial phoneme. Also, the participants in the Carter and Haarmann study were only cued to recall words from positions 2 though 6 in the phonological condition. In the present study, in contrast, participants were cued to recall from all six positions in both conditions and thus, were given more trials.

The descriptive data suggest that the Carter and Haarmann (2001) participants performing in their L1 outperformed the interpreters from the present study performing in their L2 in all cases. The most notable difference occurred in the phonological condition for short words. The difference between groups was less marked for long words in this condition. The difference between groups was even less marked in the semantic condition relative to the phonological condition, but the same general pattern emerged. That is, the greatest difference was noted for short words and a notably less difference was noted for the longer words.

The comparison to the Carter and Haarmann (2001) data also suggests that for the storage and basic processing of word-list information there is an L1 advantage. It stands to reason that interpreters may out-perform non-interpreters in a comparable version of the cued recall task in their native language. This idea is supported by Chincotta and Underwood's (1998) finding that interpreters recalled better from their L1 over their L2 in digit recall with articulation suppression while non-interpreters maintained no L1 advantage. This suggests a more robust L1 working memory storage system for interpreters. From this we may also be able to anticipate that interpreters would also do better on non-word repetition with non-words that follow the word structure rules of their native language (as opposed this study where non-words followed English phonotactics).

4.3.1. Summary

In summary, the literature on multilingual processing shows that there are differences in task performance between monolinguals and multilinguals. There are also differences when performing in an L1 versus an L2. First language processing is generally more efficient. Most of the studies to date have not looked at interpreters, however, when comparing L1 and L2 processing performance. Data from Ingrid Christoffels and colleagues (2006) suggest that interpreters perform on par in their first and secondary languages in sentences processing tasks while non-interpreters show a first language advantage. Comparison of the PSI performance in this study to the participant performance in the Carter and Haarmann (2001) study suggests that the strength of L2 performance for interpreters does not carry over to recall of unrelated word lists.

However, evidence from this study and others suggest that there may be PSI advantages in L1 relative to NIMs that merits further investigation.

4.4. Conclusions and Future Research

The growing consensus in the literature is that working memory differences between interpreters and non-interpreters are related to aspects of working memory that resemble job-related behaviors of interpreters such as repeating novel labels and listening to and responding to sets of sentences. The findings from this study support this idea. The difference between interpreters and non-interpreters is also seen to be independent of age. Age analyses indicate that older individuals are less efficient in phonological recall and tend to use more phonological-like strategies in semantic recall relative to younger individuals. These differences are found to be independent of an individual’s profession (i.e., interpreter versus non-interpreter).

Recall the potential limitations of this research discussed above regarded length of exposure to English, possible less severe foreign accent for interpreters, the pattern for earlier age of English acquisition for interpreters, the scoring protocol for the non-word repetition task, the wide age range of the older participants, and the small N. These are all areas that future research can address to substantiate or repudiate the preliminary conclusions drawn in this study.

Such tasks might include running more participants to increase the N in general, to widen the age gap between age groups, and to better equalize the age of English acquisition across the groups as well. Rescoring the non-word repetition task is another target for future research. The ideal scoring protocol for the non-word repetition task was beyond the scope of practicality for this project. It would include a third party judgment of foreign accent among the participants, a protocol that allowed for foreign accent substitutions, and acoustic measures of the participants' output.

Another consideration for future research, however, includes more novel means of performance measure. Recall the tendency for younger interpreters to achieve higher means scores than the other groups including the older interpreters despite falling short of statistical significance. This may indicate that the tasks in this study were not sufficiently sensitive to group differences. The study being performed in an L2 also needs to be considered when interpreting the findings. There is research to suggest that interpreters and non-interpreters perform differently in both their L1 and L2 skills.

To better understand interpreter/non-interpreter differences and how differences relate to job, age, and/or L1/L2 related factors, future studies may want to consider a number of approaches. In addition to increasing the number of participants in a study, participants, could be assessed in their mother or dominant language in addition to their secondarily acquired languages. Bilingual testing would ensure that the basic aspects of WM such as phonological rehearsal, storage, and semantic storage are adequately assessed. Once a comprehensive picture of basic working memory differences between these groups is established, then higher level skills such as executive function, divided attention, and sentence processing can be addressed.

Neurophysiological studies may also provide insight to cognitive differences that cannot be perceived in behavioral testing. We know that second language processing has been shown to use different strategies to achieve the same end goal, as shown in ERP studies with multilingual speakers perceiving speech sounds in noise (Maxfield et al, in preparation). Maxfield and colleagues found that bilingual university students with a mean age of 27.9 performed comparably to monolinguals with a mean age of 33.7 on behavioral measures. The ERP data, however, suggested that the bilinguals were performing differently on a cognitive level. It could be that PSIs are using their cognitive resources differently from NIMs and that behavioral tests used in the literature to date are not sensitive enough to detect differences. Perhaps this also explains the inconsistencies in the working memory literature regarding interpreters.

To conclude, the results of the present experiment suggest that working memory differences between interpreters and non-interpreters are related to aspects of working memory that are related to the task of interpreting. These differences are also maintained across the lifespan. Since the participants in this study were only tested in a non-native language more testing in both L1 and L2 needs to be conducted to ascertain actual working memory potential.

5. Tables

Table A Word Stimulus Papers

Table A Code Key For Word Stimulus Papers
1 = Relative to what is reported in the general span literature
2 = Pattern of superior interpreter performance
3 = Scores not reported, so pattern direction judgment cannot be made
4 = Student interpreters significantly better. Professionals had a pattern in the direction of better performance
PSI = Professional Simultaneous Interpreter
NIM = Non-interpreter Multilingual

Word Span Tasks							
Article	**Participants**	**Language of Testing**	**Context**	**Aural Stimuli**	**Print Stimuli**	**On Par Performance**	**Superior Interpreter Performance**
Daro & Fabbro (1994)	Student Interpreters	L1/L2	Normal	Digits			X[1]
Chincotta & Underwood (1998)	Student Interpreters, MINs	L1/L2	Normal		Digits	X[2]	
			Articulation Suppression			X[2]	
Padilla et al. (1995)	PSIs, Student Interpreters, NIMs,	NA	Normal	Digits			X
Christoffels (2006)	Interpreters, Bilingual Students, English Teachers	L1/L2	Normal		Words		X
Köpke & Nespoulous (2006)	PSIs, Student Interpreters, Multilinguals, Monolinguals	L1	Normal	Words		X[2]	

Word List Recall							
Article	**Participants**	**Language of Testing**	**Context**	**Aural Stimuli**	**Print Stimuli**	**On Par Performance**	**Superior Interpreter Performance**
			Free Recall				
Padilla et al. (1995)	PSIs, Student Interpreters, NIMs,	NA	Normal		Words	X[2]	
			Articulation Suppression				X
Köpke & Nespoulous (2006)	PSIs, Student Interpreters, Multilinguals, Monolinguals	L1	Normal	Words		X[3]	
			Articulation Suppression				X[4]
			Final Recall				
Padilla et al. (1995)	PSIs, Student Interpreters, NIMs,	NA	Normal		Words	X[2]	
			Articulation Suppression				X

Cued Recall

Article	Participants	Language of Testing	Context	Aural Stimuli	Print Stimuli	On Par Performance	Superior Interpreter Performance
Köpke & Nespoulous (2006)	PSIs, Student Interpreters, Multilinguals, Monolinguals	L1	Normal (Non-Articulation Supression)	Words Phonological Cues		X[3]	
				Words Semantic Cues		X[2]	
Signorelli et al. (2007)	PSIs, NIMs	L2			Words Phonological Cues	X[2]	
					Words Semantic Cues	X[2]	

Related Word Stimulus Tasks							
Article	**Participants**	**Language of Testing**	**Context**	**Aural Stimuli**	**Print Stimuli**	**On Par Performance**	**Superior Interpreter Performance**
Non-word Repetition							
Signorelli et al. (2007)	PSIs, NIMs	L2	Normal	Words			X
Articulation Rate for Digits							
Signorelli et al. (2007)	PSIs, NIMs	L2	Normal			X	

Table A Code Key For Phrase Stimulus Papers

1 = New students had just begun interpretation study

2 = Pattern for better performance with more interpreting experience

3 = Only student interpreters had significantly better performance than controls. Students and professionals did not differ.

PSI = Professional Simultaneous Interpreter

NIM = Non-interpreter Multilingual

Phrase Span (This is a collective term. Different studies also used labels such as reading and listening span)						
Article	Participants	Language of Testing	Aural Stimuli	Print Stimuli	On Par Performance	Superior Interpreter Performance
Padilla et al. (1995)	PSIs, Student Interpreters, NIMs,	NA		X		X
Liu (2001)	PSIs, Advanced Student Interpreters, New Students[1]	L2	X		X[2]	
Christoffels (2006)	Interpreters, Bilingual Students, English Teachers	L1/L2		X		X
Köpke & Nespoulous (2006)	PSIs, Student Interpreters, Bilinguals, Multilinguals	L1	X		X[3]	X[3]
Signorelli et al. (2007)	PSIs, NIMs	L2		X		X

Table B

Study	Participants (Interpreting experience for interpreters)	N	Age Range (years)	Mean Age
Darò & Fabbro (1994)	Student Interpreters (29 months experience on average. Experience range 12 to 60 months)	24	22 to 27 Years	24.5
Padilla et al. (1995)	Professional Interpreters (About five years experience)	5	NA	30
	Novice Interpreters (Recent Graduates)	5	NA	30
	Thrid year students with "some" interpretation training	10	NA	NA
	Second-year students with no interpretation training	10	NA	NA
	Non-interpreters	10	Post-graduates	NA
Chincotta & Underwood (1998)	Interpreters (100 Hours Experience)	24	NA	NA
	Non-interpreters	12	Undergraduate Students	NA
Christoffels (2006)	Professional Interpreters (16 Years Experience on Average)	13	NA	NA
	Non-interpreters	40	Undergraduate Students	NA
Liu (2001)	Professional Interpreters	13	NA	NA
	Student Interpreters (Half a year of experience)	12	NA	NA
	Student Interpreters (Just began training)	11	NA	NA
Köpke & Nespoulous (2006)	Professional Interpreters (17Years Experience on Average. Experience Range 4 to 35 Years)	21	29 to 61	44.4
	Student Interpreters	18	23 to 38	26.2
	Multilinguals	20	27 to 63	44.7
	Monolinguals	20	18 to 26	21.5
Present Study	Younger Professional Interpreters	12	30 to 40	34.5
	Younger Non-interpreteres	11	26 to 41	31.8
	Older Professional Interpreters	13	46 to 67	56.3
	Older Non-interpreters	11	48 to 81	63.6

Table C

Young Interpreters Language Background

Participant Code	First Language	A or Native Language (Language Interpret Into)	B or Non-native Language (Language Interpret Into)	C or Non-native Language or Interpret From
YI1	German	German	English	French / English / Italian / German
YI2	Italian	Italian	English	English / Italian
YI3	Russian	Russian	English	English / Russian
YI4	Russian	Russian	English	French / English / Russian
YI8	Polish	Polish	English	English / Polish
YI9	Spanish	Spanish	NA	English / French
YI11	German / Spanish	German / Spanish	NA	German / English
YI13	Italian	Italian	French	English / French / Spanish
YI14	German	German	French	English / French / German
YI15	Spanish	Spanish	NA	English / French
YI16	Spanish	Spanish	NA	English / French / Italian
YI17	German / English	German / English	French	German / English

Younger Interpreters Interpreting Experience

Participant Code	Duration of Interpreter Training S = Simultaneous C = Consecutive	Years of work as a simultaneous interpreter	% of time doing SI	% of time doing CI	Handedness
YI1	2.5 years (S); 3 years (C)	5 years	Most	Occasional	Right
YI2	3 years (S); 3 years (C)	16 years	60	40	Right
YI3	5 years (S); 5 years (C)	8 months	50	50	Left except writing
YI4	1 year (S); 3 years (C)	3 years	50	50	Right
YI8	1 year (Did Not Specify)	4 years	40	60	Right
YI9	4 years (S); 4 years (C)	2 years	100	0	Right
YI11	2 years (S); 2 years (C)	6 years	96	4	Right
YI13	1 year (S); 1year (C)	2 years	100	0	Right
YI14	2 years (S); 2 years (C)	2 years	100	0	Right
YI15	1 year (S); 1 year (C)	6 years	100	0	Right
YI16	2 years (S); 3 years (C)	7 years	100	seldom	Right
YI17	6 months (S); 7 months (C)	3 years	100	hardly ever	Right

Older Interpreters Language Background

Participant Code	First Language	A or Native Language (Language Interpret Into)	B or Non-native Language (Language Interpret Into)	C or Non-native Language or Interpret From
OI1	Spanish	Spanish	Spanish	English / French
OI2	Arabic	Arabic	Arabic	English / French
OI3	Spanish / French	Spanish / French	Spanish	English / French
OI4	Russian	Russian	English	English / Spanish / French / Russian
OI5	Arabic	Arabic	French	Arabic / French / English / Spanish
OI6	Dutch / German	Dutch/German	Eng	Dutch / German /English / Spanish / French
OI7	Dutch	Dutch	Italian / English	Dutch / Italian / English
OI8	German	German	English	German / English
OI9	Italian	Italian	English	English / Italian
OI10	Cantonese	Cantonese	English / Mandarin / Taishanese / Cantonese	English / Mandarin / Taishanese / Cantonese
OI12	Italian	Italian	English	English / French
OI13	French	French	NA	German / English

Older Interpreters Interpreting Experience

Participant Code	Duration of Interpreter Training S = Simultaneous C = Consecutive	Years of work as a simultaneous interpreter	% of time doing SI	% of time doing CI	Handedness
OI1	4 year (S); 2.5 years (C)	20.5 years	100	0	Right
OI2	2 years (Did Not Specify)	17 years	100	0	Right
OI3	2 years (S); 2 years (C)	17 years	100	0	Right
OI4	10 months (S); 6 months (C)	42 years	100	0	Right
OI5	1 year (S)	20years	100	0	Right
OI6	2 years (S); 2 years (C)	38 years	80	20	Right
OI7	No Formal Training	7 years	20	80	Right
OI8	No Formal Training	20 years	64	36	Right (usually)
OI9	No Formal Training	4 years	20	80	Right
OI10	8 years (S); 8 years (C)	8 years	50	50	Right
OI12	1 (S) 1(C)	32 years	84	16	Right
OI13	1 (S) 1.5 (C)	33 years	100	0	Right

Table D

Key	
1	Did Participate
0	Did Not Participate

Task Participation Roster					
Participants	Arctic Rate	Cued Recall	Non-word Repetition	Reading Span	Participated in All Four Tasks
Younger Interpreters					
YI1	1	1	1	1	1
YI2	0	1	1	1	0
YI3	1	1	1	1	1
YI4	1	1	1	1	1
YI8	1	1	1	1	1
YI9	1	1	0	1	0
YI11	1	1	1	1	1
YI13	1	1	1	1	1
YI14	1	1	1	1	1
YI15	1	1	1	1	1
YI16	1	1	1	1	1
YI17	1	1	1	1	1
N = 12	**11**	**12**	**11**	**12**	**10**
Younger Non-interpreters					
YN2	0	1	0	0	0
YN3	0	1	0	0	0
YN4	0	1	0	0	0
YN5	0	0	1	1	0
YN6	0	1	1	1	0
YN7	1	1	1	1	1
YN8	1	1	1	1	1
YN9	1	1	1	1	1
YN10	1	1	1	1	1
YN11	1	1	1	1	1
YN12	1	1	1	1	1
N = 11	**6**	**10**	**8**	**8**	**6**

Key	
1	Did Participate
0	Did Not Participate

Task Participation Roster					
Participants	Arctic Rate	Cued Recall	Non-word Repetition	Reading Span	Participated in All Four Tasks
Older Interpreters					
OI1	0	1	0	0	0
OI2	0	1	0	0	0
OI3	0	1	0	0	0
OI4	0	1	0	0	0
OI5	0	1	1	0	0
OI6	0	1	1	1	0
OI7	1	1	1	1	1
OI8	1	1	1	1	1
OI9	1	1	1	1	1
OI10	1	1	1	1	1
OI11	1	0	1	0	0
OI12	1	1	1	1	1
OI13	1	1	1	1	1
N = 13	**7**	**12**	**9**	**7**	**6**
Older Non-interpreters					
ON1	0	1	1	1	0
ON2	0	1	1	1	0
ON3	1	1	1	1	1
ON4	1	1	1	1	1
ON5	1	1	1	1	1
ON7	1	1	1	1	1
ON8	1	1	1	1	1
ON9	1	1	1	1	1
ON10	1	1	1	1	1
ON11	1	1	1	1	1
ON12	1	1	1	1	1
N = 11	**9**	**11**	**11**	**11**	**9**

Table E

Correlations

		Cued Recall ORDER Total Score	Cued Recall SEMANTIC Total Score	Non-word Repetition Total Score	Articulation Rate Total Score	Reading Span Total Score
Cued Recall ORDER Total Score	Pearson Correlation	1.00	.78(**)	0.29	-0.18	0.25
	Sig. (2-tailed)		0.00	0.11	359.00	177.00
	N	44	44	32	29	31
Cued Recall SEMANTIC Total Score	Pearson Correlation		1.00	0.20	-0.13	0.16
	Sig. (2-tailed)			0.28	0.51	0.41
	N		44	32	29	31
Non-word Repetition Total Score	Pearson Correlation			1.00	-0.02	0.20
	Sig. (2-tailed)				0.93	0.31
	N			33	25	27
Articulation Rate Total Score	Pearson Correlation				1.00	0.11
	Sig. (2-tailed)					0.60
	N				29	24
Reading Span Total Score	Pearson Correlation					1.00
	Sig. (2-tailed)					
	N					32

** Correlation is significant at the 0.01 level (2-tailed).

Table F1

Articulation Rate

Group	Artic Rate	Group	Artic Rate	Group	Artic Rate	Group	Artic Rate
OI7	4.46	ON3	5.53	YI1	5.25	YN7	6.28
OI8	5.58	ON4	7.52	YI3*	6.97	YN8*	8.57
OI9	6.26	ON5*	7.84	YI4**	5.78	YN9*	5.06
OI10	6.00	ON7	6.29	YI8	8.08	YN10	6.12
OI11	7.37	ON8	7.17	YI9	6.78	YN11	6.13
OI12	7.42	ON9	5.65	YI11	7.48	YN12	7.90
OI13	6.24	ON10*	6.66	YI14*	6.54		
		ON12	7.34	YI15	5.21		
				YI16*	6.94		
				YI17	4.88		
Mean	6.19	Mean	6.75	Mean	6.39	mean	6.68
SD	1.03	SD	0.86	SD	1.06	SD	1.30
Outliers		ON11**	9.97	YI13	9.38		

* Needed two attempts ** Needed a third attempt
Measurements are in seconds for time it took to complete task

Table F2

Non-Word Repetition											
Group	Raw Score	%correct	Group	Raw Score	%correct	Group	Raw Score	%correct	Group	Raw Score	%correct
OI1	na	na	ON1	7.00	38.89	YI1	10.00	55.56	YN2	na	na
OI2	na	na	ON2	2.00	11.76	YI2	11.00	61.11	YN3	na	na
OI3	na	na	ON3	10.00	55.56	YI3	13.00	72.22	YN4	na	na
OI4	na	na	ON4	5.00	27.78	YI4	12.00	66.67	YN5	4.00	22.22
OI5	7.00	38.89	ON5	11.00	61.11	YI8	11.00	61.11	YN6	8.00	44.44
OI6	10.00	55.56	ON7	8.00	44.44	YI11	12.00	66.67	YN7	6.00	33.33
OI7	8.00	44.44	ON8	11.00	61.11	YI13	11.00	61.11	YN8	7.00	38.89
OI8	9.00	50.00	ON9	8.00	44.44	YI14	9.00	50.00	YN9	9.00	50.00
OI9	6.00	33.33	ON10	5.00	27.78	YI15	9.00	50.00	YN10	10.00	55.56
OI11	11.00	61.11	ON11	7.00	38.89				YN11	10.00	55.56
OI12	8.00	44.44	ON12	12.00	66.67				YN12	7.00	38.89
OI13	9.00	50.00									
Mean	8.50	47.22	Mean	7.82	43.49	Mean	10.89	60.49	Mean	7.63	42.36
SD	1.60	8.91	SD	3.06	16.88	SD	1.36	7.58	SD	2.07	11.48

Table F3

Young Interpreters - Phonological Order												
	Short Words						Long Words					
Participant	I	II	III	IV	V	VI	I	II	III	IV	V	VI
YI1	100	67	83	100	83	83	83	67	33	50	67	17
YI2	83	33	33	50	83	50	50	50	50	50	17	0
YI3	83	83	83	17	0	17	67	33	33	17	0	33
YI4	100	67	67	83	50	67	67	83	33	33	50	67
YI8	50	33	33	33	17	33	50	50	0	0	0	0
YI9	100	83	100	67	83	67	100	67	17	50	17	0
YI11	100	100	100	67	83	83	100	83	50	67	83	100
YI13	67	17	50	50	50	100	100	33	17	67	50	83
YI14	80	100	50	60	33	67	67	50	0	33	67	33
YI15	67	33	67	33	67	100	67	17	67	83	83	67
YI16	67	17	67	20	33	83	33	33	17	0	50	83
YI17	83	67	33	60	100	83	50	17	17	50	50	100
Mean	**82**	**58**	**64**	**53**	**57**	**69**	**69**	**49**	**28**	**42**	**45**	**49**
SD	**17**	**31**	**24**	**25**	**31**	**25**	**22**	**23**	**20**	**26**	**30**	**39**

Table F3

Young Non-interpreters - Phonological Order												
	Short Words						Long Words					
Participant	I	II	III	IV	V	VI	I	II	III	IV	V	VI
YN2	67	67	17	67	33	17	29	0	33	33	33	33
YN3	50	50	33	17	50	100	60	0	0	0	0	67
YN4	33	50	17	0	20	67	0	17	0	17	0	20
YN6	100	33	33	83	50	33	0	33	17	50	33	50
YN7	83	33	67	17	50	67	67	50	33	0	0	83
YN8	67	17	50	0	33	67	50	50	17	33	67	33
YN9	100	83	83	83	83	83	100	17	50	40	50	67
YN10	83	67	50	100	17	80	67	83	50	67	67	80
YN11	83	83	67	67	50	83	33	50	17	50	83	40
YN12	100	67	100	100	50	33	67	67	33	83	0	33
Mean	**77**	**55**	**52**	**53**	**44**	**63**	**47**	**37**	**25**	**37**	**33**	**51**
SD	**23**	**22**	**28**	**41**	**19**	**27**	**32**	**28**	**18**	**27**	**32**	**22**

Table F3

Older Interpreters - Phonological Order												
	Short Words						Long Words					
Participant	I	II	III	IV	V	VI	I	II	III	IV	V	VI
OI1	100	33	17	33	33	67	67	17	17	17	0	67
OI2	100	50	20	33	40	67	50	17	0	0	17	50
OI3	67	0	0	0	17	83	33	0	0	0	0	100
OI4	17	17	0	17	17	83	17	0	0	17	33	83
OI5	83	0	17	67	67	100	17	33	17	40	50	67
OI6	33	33	33	0	17	17	33	33	33	17	0	17
OI7	100	83	67	83	100	100	83	67	50	83	100	100
OI8	50	17	17	33	33	83	50	0	0	17	33	67
OI9	83	33	33	0	17	0	83	0	0	0	17	17
OI10	100	83	33	83	50	50	67	50	0	17	33	67
OI12	50	50	33	0	50	17	67	33	0	0	0	83
OI13	100	100	67	50	67	83	67	33	17	67	50	83
Mean	**74**	**42**	**28**	**33**	**42**	**62**	**53**	**24**	**11**	**23**	**28**	**67**
SD	**30**	**33**	**22**	**32**	**26**	**34**	**23**	**22**	**16**	**27**	**30**	**28**

Table F3

Older Non-interpreters - Phonological Order												
	Short Words						Long Words					
Participant	I	II	III	IV	V	VI	I	II	III	IV	V	VI
ON1	83	100	100	20	50	50	100	50	33	0	33	67
ON2	100	0	50	67	83	83	67	33	17	0	33	67
ON3	83	33	0	17	33	67	50	17	0	33	50	67
ON4	50	33	17	17	0	67	33	67	17	33	33	67
ON5	83	67	100	83	100	100	83	50	50	100	100	50
ON7	83	67	50	83	67	50	83	33	17	0	17	83
ON8	67	33	17	33	100	50	67	17	17	33	67	83
ON9	100	67	83	20	50	60	50	17	0	40	50	33
ON10	33	17	0	17	33	100	67	17	0	17	33	100
ON12	17	100	50	100	67	83	17	17	17	83	50	67
Mean	**70**	**52**	**47**	**46**	**58**	**71**	**62**	**32**	**17**	**34**	**47**	**68**
SD	**28**	**34**	**38**	**34**	**32**	**20**	**25**	**18**	**16**	**34**	**23**	**18**

Table F3

Young Interpreters - Semantic Category												
	Short Words						Long Words					
Participant	I	II	III	IV	V	VI	I	II	III	IV	V	VI
YI1	83	83	83	83	100	100	100	83	50	67	67	100
YI2	50	50	83	50	50	50	83	83	83	17	33	83
YI3	67	67	83	67	67	83	83	67	33	33	33	83
YI4	83	83	100	83	100	83	67	67	83	100	100	100
YI8	50	33	17	20	83	83	17	50	40	50	33	80
YI9	100	83	67	67	83	67	83	83	67	67	50	83
YI11	67	83	67	67	100	67	33	67	67	67	100	100
YI13	50	50	67	83	67	100	17	50	80	83	83	100
YI14	100	83	67	80	83	83	83	33	20	100	100	100
YI15	33	50	67	50	100	100	33	33	100	100	67	100
YI16	50	17	50	40	100	100	67	33	33	83	100	100
YI17	67	50	50	60	67	100	83	50	50	100	100	100
Mean	**67**	**61**	**67**	**62**	**83**	**85**	**63**	**58**	**59**	**72**	**72**	**94**
SD	**21**	**23**	**21**	**20**	**17**	**17**	**29**	**19**	**25**	**28**	**29**	**9**

Table F3

Young Non-interpreters - Semantic Category												
	Short Words						Long Words					
Participant	I	II	III	IV	V	VI	I	II	III	IV	V	VI
YN2	50	83	57	33	83	100	17	33	50	83	50	100
YN3	0	17	50	83	50	100	20	50	67	67	50	100
YN4	50	33	17	50	60	83	0	17	67	83	83	100
YN6	83	50	50	83	83	100	67	33	33	33	100	100
YN7	67	67	50	50	100	83	67	83	50	67	100	100
YN8	50	50	50	50	83	67	50	67	33	50	50	83
YN9	67	83	67	50	67	100	67	67	50	60	50	83
YN10	100	83	67	100	83	100	67	83	83	83	50	100
YN11	50	50	83	83	100	83	33	17	40	83	100	80
YN12	100	50	67	50	83	83	100	50	50	67	67	83
Mean	**62**	**57**	**56**	**63**	**79**	**90**	**49**	**50**	**52**	**68**	**70**	**93**
SD	**29**	**22**	**17**	**22**	**16**	**12**	**31**	**25**	**16**	**17**	**23**	**9**

Table F3

Older Interpreters - Semantic Category												
	Short Words						Long Words					
Participant	I	II	III	IV	V	VI	I	II	III	IV	V	VI
OI1	50	67	100	50	50	100	33	50	67	17	33	100
OI2	17	33	60	17	80	100	33	33	60	67	50	100
OI3	83	67	50	33	83	100	17	33	50	50	83	83
OI4	17	0	33	33	67	100	0	0	17	83	67	100
OI5	67	67	83	83	83	100	50	50	67	100	50	100
OI6	0	0	0	50	83	83	33	33	17	0	33	83
OI7	100	100	83	83	100	100	83	33	83	100	67	100
OI8	50	67	67	83	100	100	67	0	33	83	83	100
OI9	50	17	17	17	50	83	33	0	33	67	83	83
OI10	83	33	50	67	67	100	83	33	17	83	50	67
OI12	50	67	67	50	83	100	50	33	33	67	67	100
OI13	83	83	83	83	100	100	100	67	33	100	83	83
Mean	**54**	**50**	**58**	**54**	**79**	**97**	**49**	**31**	**43**	**68**	**63**	**92**
SD	**31**	**33**	**30**	**26**	**18**	**6**	**30**	**21**	**22**	**32**	**19**	**11**

Table F3

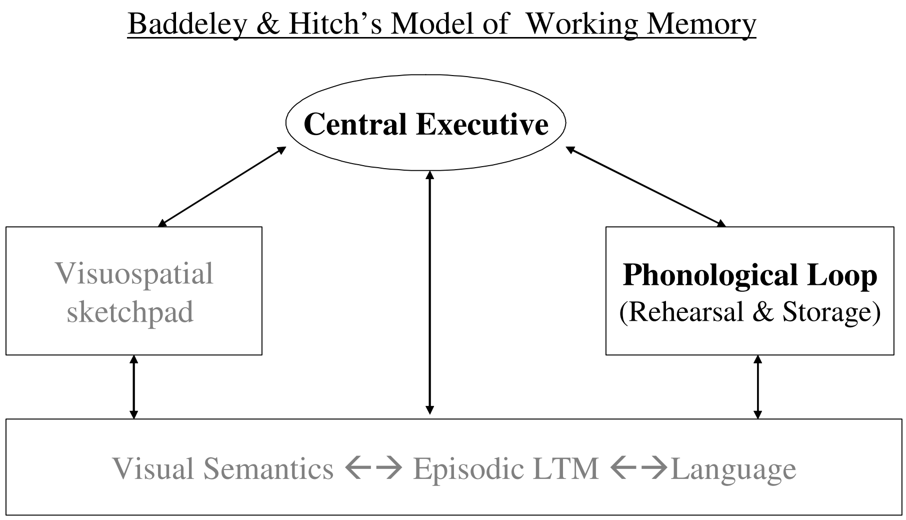
Older Non-interpreters - Semantic Category												
	Short Words						Long Words					
Participant	I	II	III	IV	V	VI	I	II	III	IV	V	VI
ON1	33	33	33	40	100	83	50	33	0	50	83	100
ON2	83	67	67	67	67	83	67	50	83	67	67	100
ON3	83	83	33	50	33	100	17	50	20	67	17	83
ON4	83	60	50	50	100	100	67	50	100	67	83	100
ON5	83	83	100	100	100	100	100	83	33	83	83	100
ON7	83	67	83	67	83	67	83	17	50	33	67	83
ON8	67	50	83	50	83	100	83	83	83	67	100	100
ON9	83	100	100	80	67	100	100	67	80	40	67	100
ON10	50	17	67	17	67	100	0	33	0	83	67	100
ON12	100	67	83	100	100	83	33	50	50	83	67	100
Mean	**75**	**63**	**70**	**62**	**80**	**92**	**60**	**52**	**50**	**64**	**70**	**97**
SD	**20**	**25**	**25**	**26**	**22**	**12**	**34**	**21**	**36**	**18**	**22**	**7**

Table F4 Reading Span

Group	Total Stimuli	Raw Score	Percent Correct	Group	Total Stimuli	Raw Score	Percent Correct	Group	Total Stimuli	Raw Score	Percent Correct	Group	Total Stimuli	Raw Score	Percent Correct
YI1	42.00	36.00	0.86	YN3	na	na	na	OI1	na	na	na	ON1	42.00	33.00	0.79
YI2	42.00	36.00	0.86	YN4	na	na	na	OI2	na	na	na	ON2	42.00	31.00	0.74
YI3	42.00	35.00	0.83	YN5	42.00	34.00	0.81	OI3	na	na	na	ON3	42.00	30.00	0.71
YI4	42.00	37.00	0.88	YN6	42.00	30.00	0.71	OI4	na	na	na	ON4	42.00	33.00	0.79
YI9	42.00	38.00	0.90	YN7	42.00	36.00	0.86	OI5	na	na	na	ON5	42.00	33.00	0.79
YI11	42.00	38.00	0.90	YN8	42.00	26.00	0.62	OI6	38.00	31.00	0.82	ON7	42.00	33.00	0.79
YI13	42.00	34.00	0.81	YN9	39.00	30.00	0.77	OI7	42.00	37.00	0.88	ON8	42.00	36.00	0.86
YI14	42.00	35.00	0.83	YN10	42.00	39.00	0.93	OI8	42.00	35.00	0.83	ON9	42.00	34.00	0.81
YI15	42.00	40.00	0.95	YN11	42.00	36.00	0.86	OI10	42.00	38.00	0.90	ON10	42.00	35.00	0.83
YI16	42.00	40.00	0.95	YN12	42.00	40.00	0.95	OI12	42.00	35.00	0.83	ON11	42.00	34.00	0.81
YI17	42.00	34.00	0.81					OI13	42.00	34.00	0.81	ON12	42.00	37.00	0.88
Mean			0.87	Mean			0.81	Mean			0.85	Mean			0.80
SD			0.05	SD			0.11	SD			0.04	SD			0.05

6. Figures

Figure 1a Baddeley & Hitch, 1974



Bold face print = Verbal working memory pertinent to this study

Figure 1b Baddeley, 2000

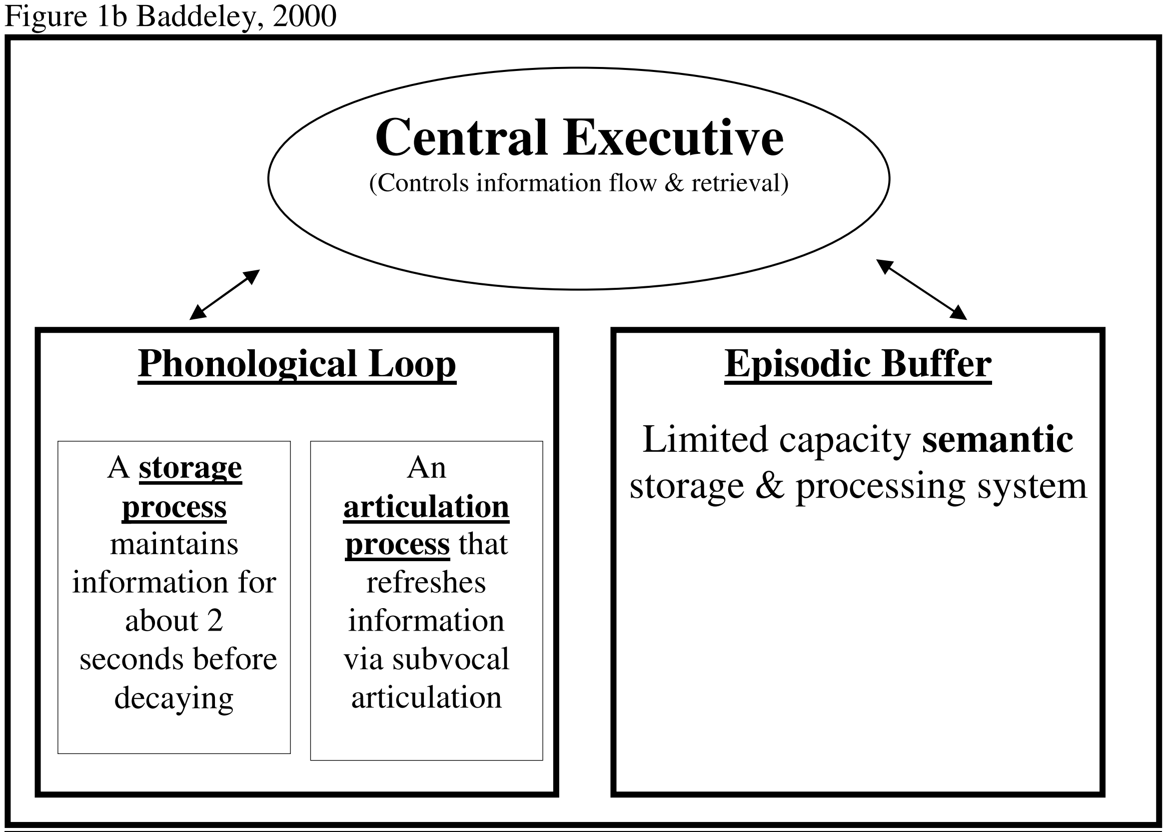


Figure 2

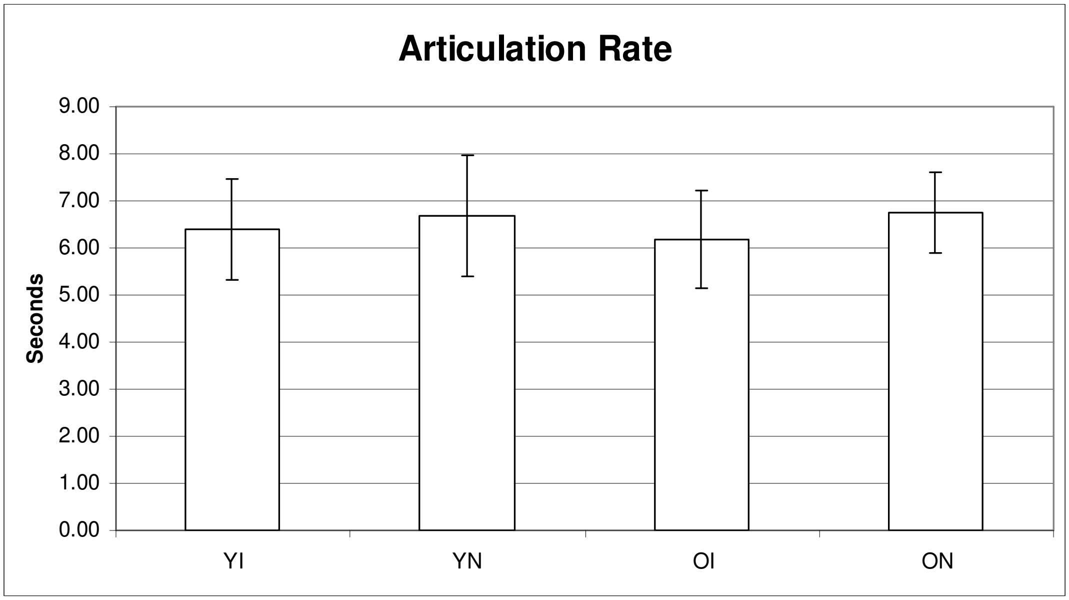


Figure 3

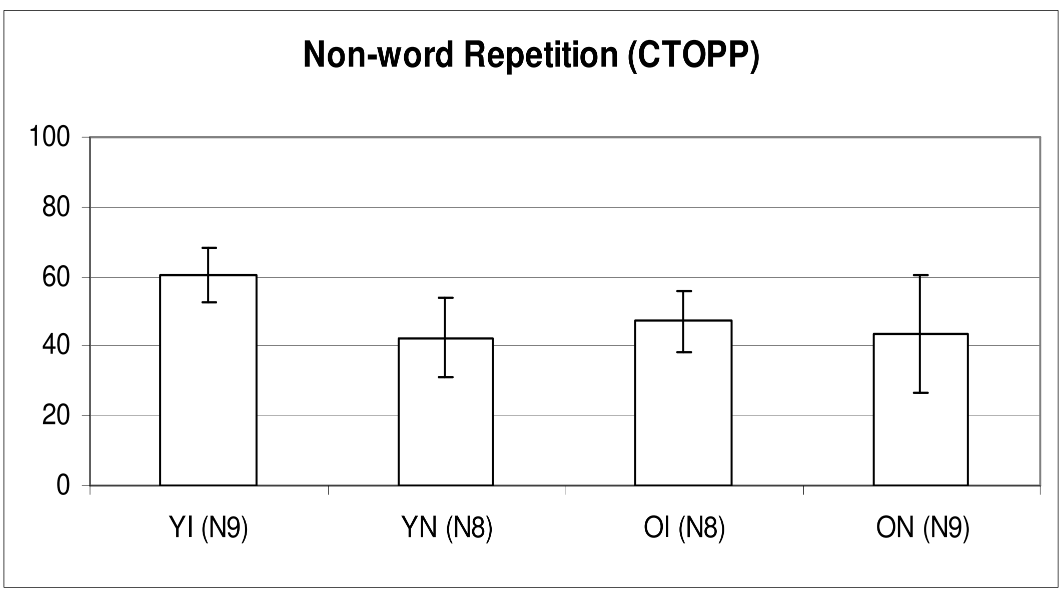


Figure 4

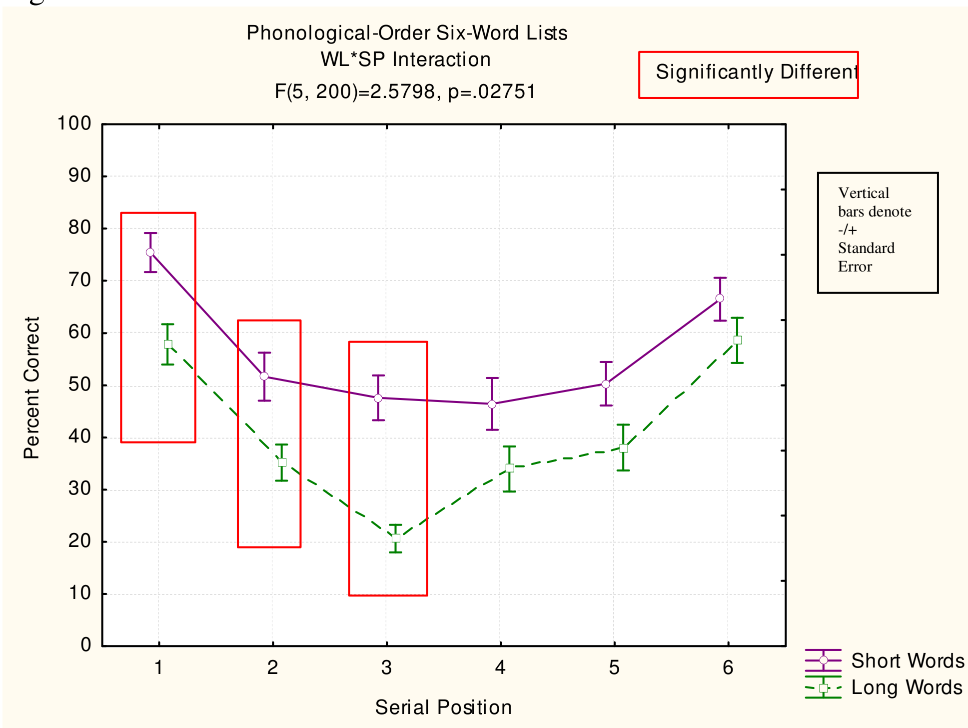

Phonological-Order Six-Word Lists
WL*SP Interaction
F(5, 200)=2.5798, p=.02751
Significantly Different
Vertical bars denote -/+ Standard Error
Percent Correct
100
90
80
70
60
50
40
30
20
10
0
1
2
3
4
5
6
Serial Position
Short Words
Long Words

Figure 5

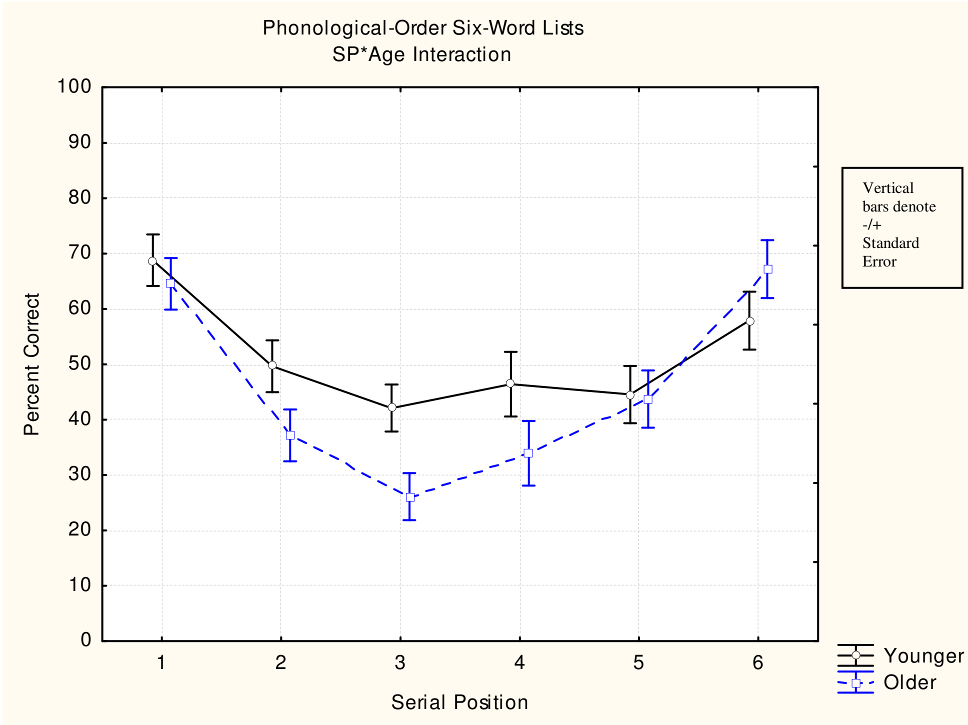
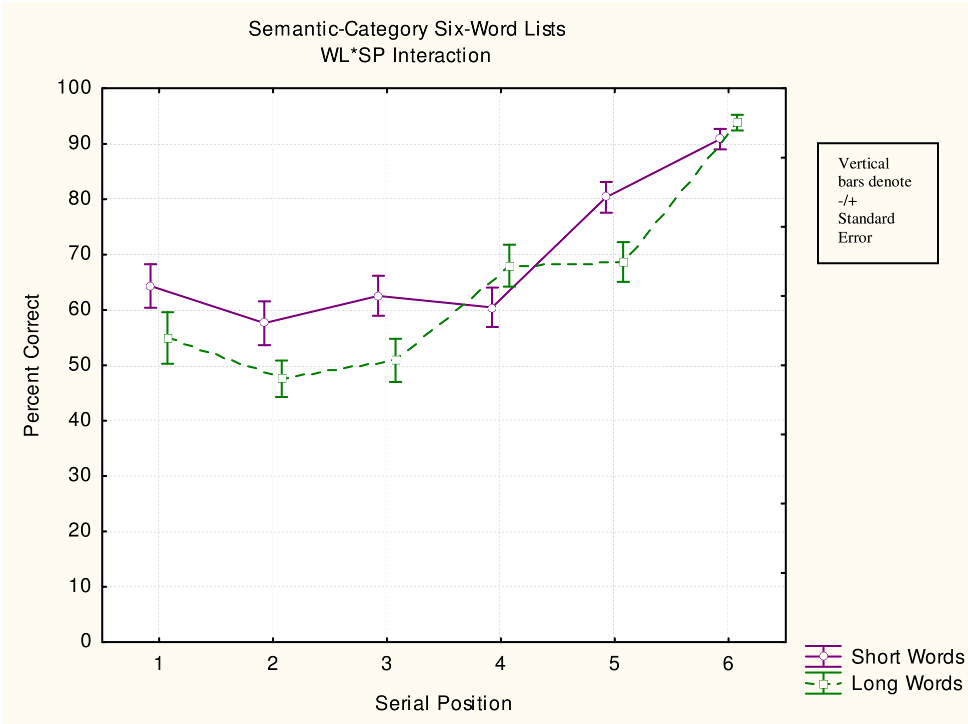

Phonological-Order Six-Word Lists
SP*Age Interaction
100
90
80
70
60
50
40
30
20
10
0
Percent Correct
1
2
3
4
5
6
Serial Position
Vertical bars denote -/+ Standard Error
Younger
Older

Figure 6



Semantic-Category Six-Word Lists
WL*SP Interaction
100
90
80
70
60
50
40
30
20
10
0
Percent Correct
1
2
3
4
5
6
Serial Position
Vertical bars denote -/+ Standard Error
Short Words
Long Words

Figure 7

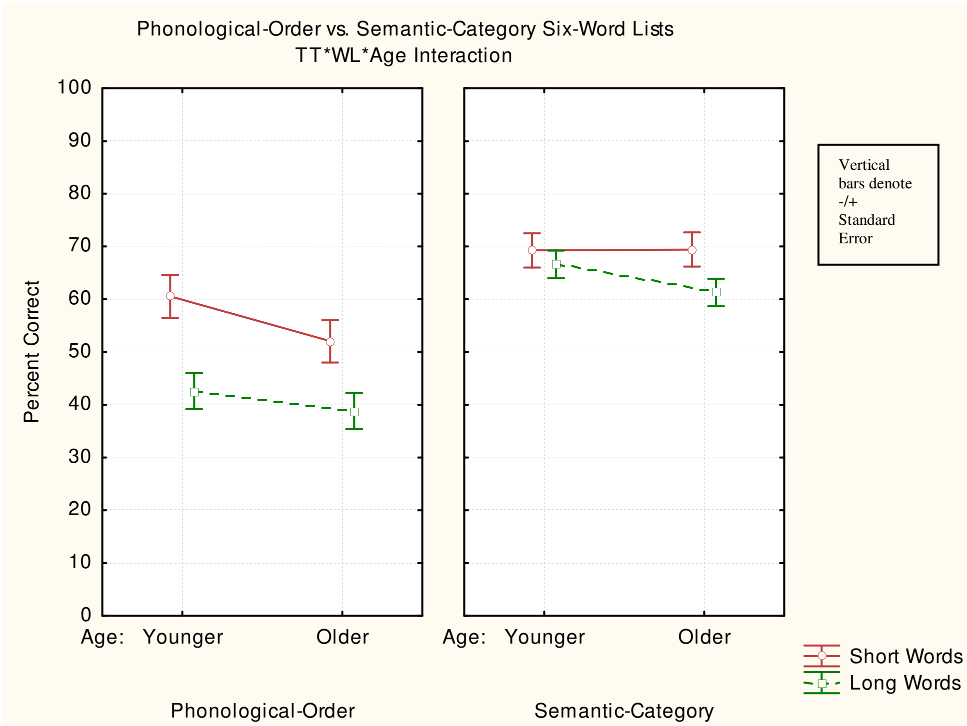

Phonological-Order vs. Semantic-Category Six-Word Lists
TT*WL*Age Interaction
Percent Correct
100
90
80
70
60
50
40
30
20
10
0
Age: Younger
Older
Age: Younger
Older
Phonological-Order
Semantic-Category
Vertical bars denote -/+ Standard Error
Short Words
Long Words

Figure 8

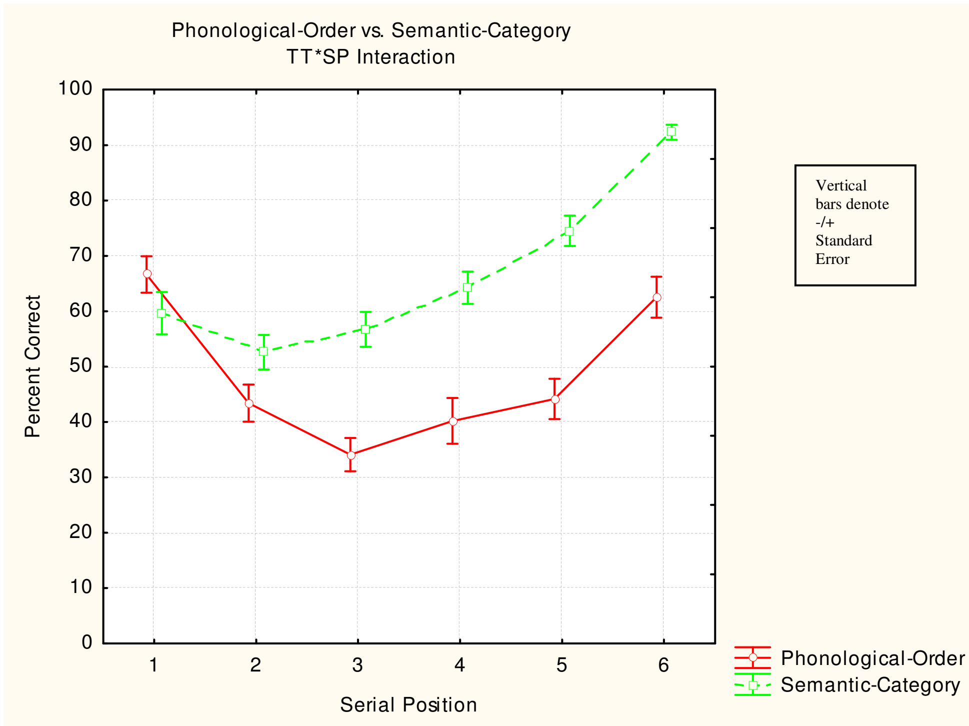
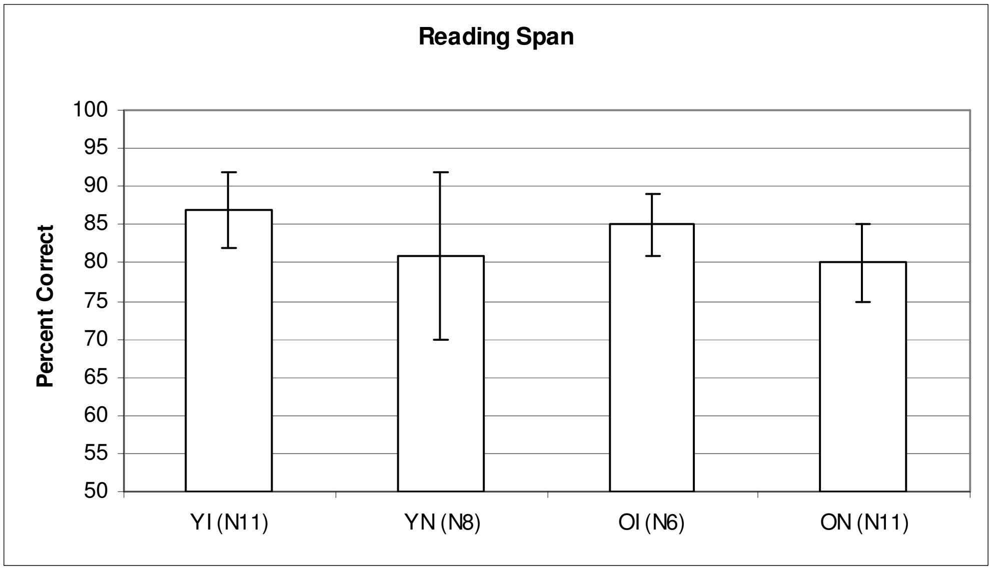

Phonological-Order vs. Semantic-Category
TT*SP Interaction
100
90
80
70
60
50
40
30
20
10
0
Percent Correct
1
2
3
4
5
6
Serial Position
Vertical bars denote -/+ Standard Error
Phonological-Order
Semantic-Category

Figure 9



Reading Span
Percent Correct
100
95
90
85
80
75
70
65
60
55
50
YI (N11)
YN (N8)
OI (N6)
ON (N11)

7. Appendices

Appendix I - Background Questionnaire

Participant Screening (for telephone)

Participant Name: ________________________ Date:

Phone Number: __________________________ E-mail: _________________

How many languages do you know?					
Languages you speak (in order of dominance)	1	2	3	4	5
Language you read	1	2	3	4	5
Language you write in	1	2	3	4	5

Lang -uage	**Age began learn-ing**	**How often used at home now?**	**How often used at work now?**	**How often used socially now?**	**Self Rated Proficiency**
1st		Everyday Few times a week Few times a month Few times a year Very seldom	Everyday Few times a week Few times a month Few times a year Very seldom	Everyday Few times a week Few times a month Few times a year Very seldom	1 2 3 4 5 Limited Survival Terms / Moderate Casual Convo / Native Complx Convo
2nd		Everyday Few times a week Few times a month Few times a year Very seldom	Everyday Few times a week Few times a month Few times a year Very seldom	Everyday Few times a week Few times a month Few times a year Very seldom	1 2 3 4 5 Limited Survival Terms / Moderate Casual Convo / Native Complx Convo
3rd		Everyday Few times a week Few times a month Few times a year Very seldom	Everyday Few times a week Few times a month Few times a year Very seldom	Everyday Few times a week Few times a month Few times a year Very seldom	1 2 3 4 5 Limited Survival Terms / Moderate Casual Convo / Native Complx Convo
4th		Everyday Few times a week Few times a month Few times a year Very seldom	Everyday Few times a week Few times a month Few times a year Very seldom	Everyday Few times a week Few times a month Few times a year Very seldom	1 2 3 4 5 Limited Survival Terms / Moderate Casual Convo / Native Complx Convo
5th		Everyday Few times a week Few times a month Few times a year Very seldom	Everyday Few times a week Few times a month Few times a year Very seldom	Everyday Few times a week Few times a month Few times a year Very seldom	1 2 3 4 5 Limited Survival Terms / Moderate Casual Convo / Native Complx Convo
6th		Everyday Few times a week Few times a month Few times a year Very seldom	Everyday Few times a week Few times a month Few times a year Very seldom	Everyday Few times a week Few times a month Few times a year Very seldom	1 2 3 4 5 Limited Survival Terms / Moderate Casual Convo / Native Complx Convo

Simultaneous Interpreting Background Questions

Are you presently working as an SI? **Y** **N**

How long have you been an SI?

How often do you work? (e.g., at least 50% full time that of a typical SI)

Languages of interpretation:

Active (interpret into):

Passive (interpret from):

What is your formal training?

Non-Interpreter Bilingual Professional Questions

What is your occupation?

How many languages do you use at work and to what gross percentages?

Does your job or personal life ever require that you interpret from one language to another, if so, how often and with which languages?

All Potential Participants

Do you have a known history of neurological problems or head injuries (e.g., Head trauma, car accident, history of concussions, stroke, seizures)?

Do you have a history of learning or reading difficulty?

Do you have any vision or hearing problems?

<u>Background Questionnaire – Cover Page</u>

Dear Volunteer,

Thank you for agreeing to participate.

Enclosed you'll find a questionnaire that primarily asks for information regarding the languages you speak, how you learned them, and how you use them.

Believe it or not, these factors can effect how you perform in language and memory tasks.

The information I obtain in this questionnaire will help me understand and interpret your performance relative to the other participants who may speak different languages and may have learned them in different ways.

There are a fair number of questions, so please, take your time and feel free to fill out the forms at your leisure. It is not necessary to fill out everything in one sitting., but if you can, try to fill out the questionnaire before arriving for the experimental session.

A number of the questions ask you to estimate hours, years, ages, percentages etc. Please **give your best guess** and know that **gross estimates are sufficient**.

There are also some other questions about your educational and occupational background. This will also help me interpret your performance in the experimental tasks relative to other participants from varied backgrounds.

Please remember, as stated, all information collected in this process will be kept **completely confidential**.

Results from this experiment will help us better understand how memory works so that we can help others, who need to, improve their memory.

Thanks again for your participation. Your time is truly appreciated.

Sincerely,

Teresa
tsignorelli@gc.cuny.edu

<u>**Background Questionnaire**</u>

Please fill out the requested information to the best of your knowledge. Feel free to add any information you feel might be relevant using the back of the page if necessary.

Section A: The following questions regard general biographical information

Date: ________________________ e-mail address:

____

Address:

____

____

Telephone Numbers: (Home) __________________ (Work) _______________________

Date of Birth: ________________ Age: _____________ Gender: Male Female

Birthplace: ____________________________ _________________________________

(Town/City) (State/Country)

Years of education after high school __________________

Degrees Earned: ____

What languages do you speak now? 1. _____________ 2. ______________________

3. __________________ 4. __________________5. __________________

What languages do you read now? 1. _______________ 2. ______________________

3. __________________ 4. __________________5. __________________

What languages do you write in now? 1. ____________ 2. ______________________

3. __________________ 4. __________________5. __________________

What language(s), if any, did you speak/understand as a child (before going to school) that you lost? Please report by what age you no longer were able to use that language.

1. ____________________ 2. ______________________ 3. __________________

4. __________________5. __________________

List any languages you were exposed to regularly but did not learn:	
Language	**How often you heard it**

Do you like learning foreign languages?

Do you feel you have particular difficulty learning foreign languages?

Do you feel you have particular talent for learning foreign languages?

Do you have a known history of difficulty with speech, language, reading, or learning in general? Is so please explain.

Which is your dominant hand (e.g., Which hand would you use to throw a ball, answer the phone, stir a pot?)

Please list places you have lived			
Country	Time there (gross estimates are fine)	Was the dominant language of the country Spoken at home? Please list home language/s.	Was this the language of your Schooling? If not please list.
	From age to age	Yes No **Language/s:**	Yes No **Language:**
	From age to age	Yes No **Language/s:**	Yes No **Language:**
	From age to age	Yes No **Language/s:**	Yes No **Language:**
	From age to age	Yes No **Language/s:**	Yes No **Language:**
	From age to age	Yes No **Language/s:**	Yes No **Language:**
	From age to age	Yes No **Language/s:**	Yes No **Language:**
	From age to age	Yes No **Language/s:**	Yes No **Language:**

Person	Birth Place	Person’s Dominant Language	Other languages spoken in order of dominance
Parent 1			
Parent 2			
Parent 3			
Sibling 1			
Sibling 2			
Sibling 3			
Gradparent1a			
Grandparent 1b			
Grandparent 2a			
Grandparent 2b			
Other			
Other			

Section B: The following questions regard the languages you know. Please fill out a different form for each of the languages you speak.

Language:

Age began learning		
Age began reading		
Age began writing		
Was this the language you attended school in	Yes	No
If schooling took place in this language, please list which grades. Include preschool through University and Graduate School where applicable.		
If not schooling did not take place in this language please list year/months/grades of formal study		
Age proficiency reached		

Do you actively try to improve your skills in this language and if so, How?

How did you learn this language?				
I learned to speak	I develop-ed listening comprehend-sion	I learned to Read	I learned to write	
				a1. at school in general instruction
				a2. at school as a subject Hrs/Wk
				b. at home. Time language was used for this task __________ %
				c. at an afternoon course. Hrs./Week ______
				d. in a country where spoken (initially)
				e. in a country where spoken
				f. through relatives. Please state with whom and how often:
				g. exposure in neighborhood. Please state with whom and how often:
				Exposure to television. Hrs./Wk _________
				Exposure to radio. Hrs./Wk ______________
				Exposure to books, newspapers. Hr/Wk ______
				Other:

How Learned to:	Speak	Comprehend	Read	Write	
(check any that apply)					Classroom, mostly conversation
					Classroom mostly grammar
					Classroom, mostly translating from L1
					Classroom mostly, reading
					Classroom, all skills equally
					By spending time in country where spoken
					Through exposure at home
					Improved through reading
					Self-study
					Other

How often used in past year	Speak	Comprehend	Read	Write	
					Most of the day
					Few hours a day every day
Check one for each column					More than 6 hours a week
					Once a month
					Once every few months
					Once a year
					Hardly every
					Other

Fill in the approximate percentage of the time for all that apply

Where used to:	**Speak**	**Listen**	**Read**	**Write**	
	%	%	%	%	
					A. At home…
					A1 with or to a spouse or partner
					A2 with or to children
					A3 with or to parents
					A4 with or to grandparents
					A5 with or to other relatives
					A6 with other
					B. **at school**
					B1. **With instructor**
					B2. With other students
					C. at work
					C1. **With colleagues**
					C2. **With clients/patients**
					D. in free time
					D1 with friends in daily life
					D2. friends other
					E. Time used with native speakers
					k. other

How often speak	Circle any that apply
	a. most leisure time
	b. about half of leisure time talking
	c. a small part of leisure talking
	d. most of work time talking
	e. about half of work talking
	f. a small part of work talking
	g. hardly ever
	h. other

How often read	Circle any that apply
	a. Most leisure reading. Please list how often and what type of media (literature, newspapers, non-fiction)
	b. about half of leisure reading
	c. a small part of leisure reading
	d. most reading for work
	e. about half of work reading
	f. a small part of work reading
	g. hardly ever
	h. cannot read this language
	i. other

How often write	Circle any that apply
	a. most leisure time (e.g., email, letters, post cards)
	b. about half of leisure time writing
	c. a small part of leisure writing
	d. most writing for work
	e. about half of work writing
	f. a small part of work writing
	g. hardly ever
	h. cannot write in this language
	i. other

How often watch TV/movies	Circle any that apply
	a. most of the time
	b. about half of the time
	c. a small part of the time
How often listen to radio	a. most of the time
	b. about half of the time
	c. a small part of the time
How often listen to radio	a. most of the time
	b. about half of the time
	c. a small part of the time
How often attend religious services	a. most of the time
	b. about half of the time
	c. a small part of the time

Can use this language to:					
	Buy train tickets	Yes	probably	barely	no
	Read road signs	Yes	probably	barely	no
	Explain your job	Yes	probably	barely	no
	Make small talk	Yes	probably	barely	no
	Discuss the news	Yes	probably	barely	no
	Read the newspaper	Yes	probably	barely	no
	Discuss literature	Yes	probably	barely	no
	Read a classic novel	Yes	probably	barely	no
	Argue an opinion	Yes	probably	barely	no

Please rate your language skills as best you can:

Overall Skill:						
1	2	3	4	5	6	7
limited knowledge		good knowledge but not fully proficient		very proficient but not quite native- like		native-like knowledge
Speaking Skills						
1	2	3	4	5	6	7
limited knowledge		good knowledge but not proficient		very proficient but not quite native- like		native-like knowledge
Listening Comprehension Skills						
1	2	3	4	5	6	7
limited knowledge		good knowledge but not proficient		very proficient but not quite native- like		native-like knowledge
Reading Skills						
1	2	3	4	5	6	7
limited knowledge		good knowledge but not proficient		very proficient but not quite native- like		native-like knowledge
Writing Skills						
1	2	3	4	5	6	7
limited knowledge		good knowledge but not proficient		very proficient but not quite native- like		native-like knowledge

<u>**Simultaneous Interpreting Background Questionnaire**</u>

The following questions regard the nature of your training and work as a professional simultaneous interpreter (PSI)

Please list the years/months of training have you had in
Translation:
Consecutive Interpreting:
Simultaneous Interpreting:

Where did you receive your training?

What degree, licenses, and certifications do you have? Please list dates you received them.

Please state a brief history of your employment as a PSI.

Location	Beginning date	End date	Active language (s)	Passive language (s)

Please describe the frequency and duration of the time you simultaneously interpret in your present job (e.g., Three days a week, for a half hour at a time, with half hour breaks across four hours; … etc.). Please include a description of the active & passive languages these times pertain to.

How long have you been working as a PSI at this frequency and duration?

Please describe the frequency and duration of the time you interpret consecutively (e.g., Three days a week, for a half hour at a time, with half hour breaks across four hours; … etc.) Please include a description of the active & passive languages this description pertains to.

How long have you been interpreting consecutively at this frequency and duration?

Please describe any other information you feel might be pertinent regarding your background as a PSI.

What are the languages you interpret from?

What are the languages you interpret into?

Please estimate the time you spend interpreting to and from these languages.

<u>Non-Interpreter Bilingual Professional Questionnaire</u>

The following questions regard the nature and degree to which you use your languages at work

Please state your occupation and a brief job description.

Please describe what language/s you use in your job and what capacity you use them and in what proportion of you day (e.g., Speak English 30% of the day and French 70% of the day; Write in French 50% of the day and Italian 25% and English 25%)

<u>Capacity   Percent of the day</u>
Writing

Reading

Speaking

Does your job ever require that you interpret from one language to another?

Daily, weekly, monthly, rarely, other ___________

Please describe the situation in which this occurs, how long it takes place, and how often (e.g., twice weekly for an hour long meeting regarding school placement for a disabled child; on occasion when a client who doesn't speak English visits the office)

Does your life outside ever require that you interpret from one language to another (e.g., for family members)?

Daily, weekly, monthly, rarely, other ___________

Please describe the situation in which this occurs, how long it takes place, and how often.

Background Questionnaire

Please fill out the requested information to the best of your knowledge. Feel free to add any information you feel might be relevant using the back of the page if necessary.

Occupation: ____________________ Years of education after high school __________________

Degrees Earned: ____

13. Do you like learning foreign languages?

14. Do you feel you have particular difficulty learning foreign languages?

15. Do you feel you have particular talent for learning foreign languages?

16. Do you have a known history of difficulty with speech, language, reading, or learning in general? Is so please explain.

Do you have a known history of neurological problems or head injuries (e.g., Head trauma, car accident, history of concussions, stroke, seizures)?

Do you have a history of learning difficulty?

Which is your dominant hand (e.g., Which hand would you use to throw a ball, answer the phone, stir a pot?)

Appendix II

CTOPP Nonword Stimuli

List A (CTOPP)

	Orthographic Form	Phonetic Transcription
a	ral	rael
b	sart	sart
c	ballope	baelop
1	joop	jup
2	zid	zId
3	pate	pet
4	meb	mEb
5	wudoip	wudcip
6	nigong	naigang
7	chaseedoolid	chaesiduLId
8	byeleedoje	baiLidoj>
9	voesuhtoove	voze_tuv
10	Lissashrul	Lise_shrUL
11	woolanawup	wuLaene_wV_p
12	teebudeyeshawlt	tibUdaishc_lt
13	viversoomouje	vIvErsumauj>
14	burlooguhgendaploe	bErLuge_j>Ende_pLo
15	geckiezaisaykad	gEkizaisekaed
16	mawgeebooshernooshaik	magibushErnushaik
17	dookershatupietazam	dukErshate_paite_zam
18	shaburaihUhvoymush	shabEraihV_vcimV_sh

Appendix III

Cued Recall Stimuli

Short

	Category	1	2	3	4	5	6	7	8
1	ANIMAL	pig	worm	mule	beaver	mouse	wolf	camel	ape
2	MUSIC	harp	drum	fiddle	alto	trumpet	choir	flute	tenor
3	NATURE	swamp	cliff	hail	smog	drizzle	brook	dew	sleet
4	MEDICAL	germ	ulcer	spasm	wound	scar	sting	ache	rash
5	OCCUPATION	grocer	miner	jockey	tailor	singer	butcher	nun	banker
6	FOOD	peach	bean	jam	dip	carrot	apple	herb	gravy

Long

	Category	1	2	3	4	5	6	7	8
1	ANIMAL	butterfly	alligator	rhinoceros	rattlesnake	cardinal	caterpillar	elephant	crocodile
2	MUSIC	clarinet	harpsichord	percussion	accordion	philharmonic	baritone	saxophone	tambourine
3	NATURE	waterfall	hurricane	archipelago	avalanche	reservoir	embankment	wilderness	peninsula
4	MEDICAL	penicillin	inoculation	tuberculosis	antibiotic	infirmary	rheumatism	ambulance	infection
5	OCCUPATION	librarian	psychologist	aviator	mechanic	astronaut	fisherman	journalist	carpenter
6	FOOD	pineapple	cauliflower	spaghetti	chocolate	raspberry	broccoli	asparagus	sauerkraut

Appendix IV

Reading Span Stimuli

1 My uncle's favorite pastimes are reading and sleeping on the beach.
2 The letter was lost because it did not have a postage stamp.

3 The first driver out in the morning always picks up the mail.
4 Getting up was difficult this morning because I had a nice dream.

5 The state of Wisconsin is famous for its butter and cheese.
6 The last thing he did was to take a nice hot bath.

7 During the biology class the teacher showed a picture of the brain.
8 At night the prisoners escaped through a hole in the floor.
9 All morning the two children sat and talked in the park.

10 All that remained in the lunch box was one salted nut.
11 The first thing he does every morning is swing a golf club.
12 We had to stop driving because the car produced a lot of steam.

13 The letter said to come to the market and claim the prize.
14 At the top of a tall tree sat a bird singing its song.
15 This sweater itches your skin because it is made of pure wool.

16 He played baseball all day at the park and got a sore arm.
17 She soon realized that the man forgot to leave the room key.
18 I have had no luck since I tripped over that black cat.
19 He ate some of the bread quickly and then washed the plate.

20 The boy was surprised to learn that milk came from a cow.
21 The people in northern Europe always like to travel by boat.
22 There were so many people that I couldn't find a seat.
23 They decided to take an afternoon break by a large rock.

24 Unfortunately, he overslept and missed all of the morning economics class.
25 Recently, we went to see the newly born animals on the farm.
26 The children have a lot of fun when they visit the old mill.
27 The drinks were all gone and all that remained was the food.

28 The most frightening experience was getting stuck in a dark cave.
29 Suddenly the taxi opened its door in front of a bank.
30 Two kinds of popular foods in the summer are melon and sweet corn.
31 The clerk in the department store put the present in a bag.
32 He looked across the room and saw a person holding a gun.

33 There was nothing left to do except leave and lock the door.
34 The only thing left in the kitchen cupboard was a broken cup.
35 The boat engine would not run because it was out of oil.
36 When he fell he hurt his knee and found a rare coin.
37 The young woman and her boyfriend thought they saw a wolf.

38 I had a wonderful holiday but I came back with a nasty cough.
39 The season that most people often associate with love is spring.
40 The only thing she wanted was a nice cup of tea.
41 She took a deep breath and reached into the rusty box.
42 The skiing was so wonderful that I didn't mind the snow.

Appendix V

Phonology/Order

Codes	Number of Words not known	Percentage of words not known	Number of trials eliminated	Percentage of trials eliminated
YI1	0	0.00%	0	0.00%
YI2	0	0.00%	0	0.00%
YI3	0	0.00%	0	0.00%
YI4	0	0.00%	0	0.00%
YI5	0	0.00%	0	0.00%
YI8	0	0.00%	0	0.00%
YI9	0	0.00%	0	0.00%
YI11	1	1.04%	1	0.83%
YI13	0	0.00%	0	0.00%
YI14	4	4.17%	4	3.33%
YI15	1	1.04%	1	0.83%
Y16	3	3.13%	3	2.50%
YI17	1	1.04%	1	0.83%
.				
YN3	3	3.13%	3	2.50%
YN4	3	3.13%	3	2.50%
YN6	0	0.00%	0	0.00%
YN7	0	0.00%	0	0.00%
YN8	1	1.04%	1	0.83%
YN9	1	1.04%	1	0.83%
YN10	4	4.17%	4	3.33%
YN11	2	2.08%	2	1.67%
YN12	0	0.00%	0	0.00%
.				
OI1	0	0.00%	0	0.00%
OI2	4	4.17%	4	3.33%
OI3	0	0.00%	0	0.00%
OI4	0	0.00%	0	0.00%
OI5	1	1.04%	1	0.83%
OI6	0	0.00%	0	0.00%
OI7	0	0.00%	0	0.00%
OI8	0	0.00%	0	0.00%
OI9	0	0.00%	0	0.00%
OI10	1	1.04%	1	0.83%
OI12	0	0.00%	0	0.00%
OI13	0	0.00%	0	0.00%
.				
ON1	1	1.04%	1	0.83%
ON2	0	0.00%	0	0.00%
ON3	1	1.04%	1	0.83%
ON4	0	0.00%	0	0.00%

ON5	0	0.00%	0	0.00%
ON7	0	0.00%	0	0.00%
ON8	0	0.00%	0	0.00%
ON9	6	6.25%	6	5.00%
ON10	0	0.00%	0	0.00%
ON11	0	0.00%	0	0.00%
ON12	0	0.00%	0	0.00%

Semantic/Category

Codes	Number of Words not known	Percentage of words not known	Number of trials eliminated	Percentage of trials eliminated
YI1	0	0.00%	0	0.00%
YI2	0	0.00%	0	0.00%
YI3	0	0.00%	0	0.00%
YI4	0	0.00%	0	0.00%
YI5	0	0.00%	0	0.00%
YI8	3	3.13%	3	2.50%
YI9	0	0.00%	0	0.00%
YI11	1	1.04%	1	0.83%
YI13	1	1.04%	1	0.83%
YI14	1	0.01%	1	0.83%
YI15	0	0.00%	0	0.00%
Y16	3	3.13%	3	2.50%
YI17	1	1.04%	1	0.83%
.				
YN3	3	3.13%	3	2.50%
YN4	3	3.13%	3	2.50%
YN6	0	0.00%	0	0.00%
YN7	0	0.00%	0	0.00%
YN8	1	1.04%	1	0.83%
YN9	1	1.04%	1	0.83%
YN10	4	4.17%	4	3.33%
YN11	3	3.13%	3	2.50%
YN12	0	0.00%	0	0.00%
.				
OI1	0	0.00%	0	0.00%
OI2	4	4.17%	4	3.33%
OI3	0	0.00%	0	0.00%
OI4	0	0.00%	0	0.00%
OI5	0	0.00%	0	0.00%
OI6	0	0.00%	0	0.00%
OI7	0	0.00%	0	0.00%
OI8	0	0.00%	0	0.00%

OI9	0	0.00%	0	0.00%
OI10	1	1.04%	1	0.83%
OI12	0	0.00%	0	0.00%
OI13	0	0.00%	0	0.00%
.				
ON1	1	1.04%	1	0.83%
ON2	0	0.00%	0	0.00%
ON3	1	1.04%	1	0.83%
ON4	4	4.17%	4	3.33%
ON5	0	0.00%	0	0.00%
ON7	0	0.00%	0	0.00%
ON8	0	0.00%	0	0.00%
ON9	6	6.25%	6	5.00%
ON10	0	0.00%	0	0.00%
ON11	0	0.00%	0	0.00%
ON12	0	0.00%	0	0.00%

8. Footnotes

1. One YI, YI7, who was eliminated, came over two sessions. One session was for cued recall and the second for the remaining tasks.

The number of stimulus words in the cued recall task that he was unfamiliar with well exceeded 5% of the corpus. This, combined with his limited interpreting experiences relative to other interpreters, and his comments that he was using intuition instead of his memory skills to perform the other experimental tasks led to the decision to remove his data from the data base.

Another YI, YI8, became too physically fatigued to continue testing on her first visit for participating in the experiment. She reported having a very hard work day and asked to stop testing after three CR trials. She returned a month later and testing continued from the very beginning. Her second set of data are included in the analysis set.

2. One participant, ON1, was scored on-line as the task progressed. Due to a technical malfunction a recording of the task was not made. The data for this participant were included, nonetheless.

3. The data from Participant OI11 were excluded from analyses of this task because she only completed one condition secondary to her personal time constraints.

4. YN2, who was run in the pilot phase, had a slightly different number of trials per position due to list-construction flaws.

5. The stimuli were also distributed into lists of four words in length which were presented to the participants. Since the six-word lists were more discriminating and there were no contradictory findings between the list lengths, only the six-word lists are reported in the dissertation.

6. It is important to note that during the experiment the participants sat through 120 trials which included a set of four-word lists intermixed with the six-word lists. A potential cognitive fatigue factor should be considered when comparing performance here to other studies as a result.

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