# THE ROLES OF WORKING MEMORY, LANGUAGE PROFICIENCY, AND TRAINING IN SIMULTANEOUS INTERPRETATION PERFORMANCE: EVIDENCE FROM CHINESE-ENGLISH BILINGUALS

A Dissertation

by

YEH-ZU TZOU

Submitted to the Office of Graduate Studies of
Texas A&M University
in partial fulfillment of the requirements for the degree of

DOCTOR OF PHILOSOPHY

August 2008

Major Subject: Curriculum and Instruction

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August 2008

Major Subject: Curriculum and Instruction

## ABSTRACT

The Roles of Working Memory, Language Proficiency, and Training in Simultaneous Interpretation Performance: Evidence from Chinese-English Bilinguals.

(August 2008)

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Simultaneous interpretation is a cognitively demanding task involving concurrent listening and speaking in two languages. Successful performance in this task likely relies on a good working memory, which reflects a person's ability to process and store information simultaneously. The present study used the theoretical construct of working memory to investigate the task of simultaneous interpretation. Twenty student interpreters at two different levels of training in interpreting and sixteen bilinguals with no training in interpreting, all of whom spoke Chinese as a first language and English as a second language, participated in this study. They were compared on their performance for two measures of working memory – reading span and digit span – and on a simultaneous interpretation task. In addition, a translation judgment task and proficiency self-evaluation measures were administered to explore if language proficiency mediates working memory in participants' L1 (native language) and L2 (second language). This study also examined the relation between working memory and performance in simultaneous interpretation.

Results showed that the student interpreters performed better than bilinguals on simultaneous interpretation. Advanced-level student interpreters also outperformed bilinguals on all language versions of the memory span tasks, though first-year student interpreters did not show higher working memory than the bilinguals. Further, performance in simultaneous interpretation was related to working memory in both L1 and L2. Based on the study’s findings, two years of training in interpreting seemed to have a positive effect on improving working memory, whereas one year of training in interpreting did not help to increase working memory. On the other hand, higher language proficiency did not result in high working memory but contributed to better performance in simultaneous interpretation. Working memory, it is concluded, is important but language proficiency in L1 and L2 assumes a more critical role in simultaneous interpretation performance.

To my parents

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# CHAPTER I

# INTRODUCTION

## PROBLEM STATEMENT

Since the Nuremberg War Crimes Tribunal adopted simultaneous interpretation as a new mode of translation in its trials in 1945, simultaneous interpretation has been introduced into nearly every international meeting, conference, and trial. Simultaneous interpretation is a complex skill that places heavy demands on an individual's cognitive resources mainly because the task involves concurrent listening and speaking in two languages. While engaging in simultaneous interpretation, not only does the interpreter need to comprehend the input message, s/he has to temporarily store the information for later retrieval while at the same time process an earlier part of the speaker's speech and then produce it in another language. Thus, simultaneous interpreters have been regarded as highly proficient bilingual or multiple language speakers who have acquired superior second language skills that often serve as exemplars to other bilinguals. In addition, outside observers who are intrigued by interpreters' ability to achieve the seemingly "impossible feat" of simultaneous interpretation would be most interested in learning about the skills that are most relevant to simultaneous interpreting.

Psychologists and psycholinguists, in attempting to understand an online processing task such as simultaneous interpretation, have tried to break down the task into separate

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This dissertation follows the style of *Interpreting*.

components in order to identify the critical sub-skills in simultaneous interpretation. One such sub-skill is working memory (WM), which many researchers (e.g., Bajo, Padilla, & Padilla, 2000; Christoffels, De Groot, & Waldorp, 2003) have found to be associated with performance in simultaneous interpretation. Working memory, as it relates to interpreting, refers to the ability of an individual to process and store information at the same time, a skill that is required of simultaneous interpreters. Other examples of cognitive tasks that tax working memory are language comprehension (Daneman & Merikle, 1996), reasoning, and following directions (Gathercole, 1999). In language comprehension, for instance, individuals need working memory to recall earlier parts of a spoken message until they can be integrated with the later parts. In student academic performance, individuals who differ in the capacity of their various working memory subsystems have been found to differ in terms of scholastic achievement (Baddeley, 2006).

## BACKGROUND

In studying interpreters and ordinary bilinguals, several researchers have established that having a large working memory is a critical skill in simultaneous interpretation for bilinguals untrained in interpreting (Christoffels et al., 2003). Further, efficient use of working memory is also what distinguishes interpreters from bilinguals who do not have prior training in interpreting[1] (Christoffels, De Groot, & Kroll, 2006). On the other hand, other researchers have found that professional interpreters do not

[1] Training in interpreting or interpreting training, in this study, refers to training in simultaneous interpretation. However, the student interpreters in this study were also trained in consecutive interpretation, which is another form of interpreting.

necessarily have a higher working memory capacity than those who have less experience in interpreting (novice interpreters) (Köpke & Nespoulous, 2006; Liu, Schallert, & Carroll, 2004), suggesting that differences in working memory may not be the only determinants of performance, or more precisely, expertise in interpreting.

The fact that working memory has been the focus of many experimental studies on simultaneous interpretation has much to do with the heavy demand that this task imposes on one's memory load. During simultaneous interpretation, the interpreter is required to "juggle" two languages at the same time and since most language combinations differ in sentence structure, the job of the interpreter is made even more challenging. When listening to a speech delivered in German, for example, the simultaneous interpreter needs to wait for the verb that concludes the sentence before its translation into English can be produced. For interpreters working between Chinese and English, different sentence orders may also prevent them from immediately producing the output in the target language (Chinese) upon hearing the first few words of a sentence in the source language (English). The interpreter is often advised to wait as long as possible so that some potential ambiguities can be resolved by the context. This long lag between input and output necessarily puts a greater burden on the interpreter's memory load.

In light of the important role that working memory appears to play in simultaneous interpreting, the theoretical construct of working memory was adopted in the present study to explore how Chinese-English bilinguals untrained in interpreting and those who are at different levels of training in interpreting are differentially affected by working memory resources when engaging in the cognitively demanding task of simultaneous interpreting. The simultaneity of comprehension and production is not the only difficulty involved in simultaneous interpretation. Two different languages compete for the attention of the interpreter as s/he listens to input in one language and produce its translation in another. In more specific terms, several processes take place during interpreting which require working memory: (a) Analysis and understanding of the source language (L1) speech; (b) Reformulation of L1 into L2 (target language); (c) Storage of information in WM; (d) Production; and (e) Control (Gile, 1997). In order for interpretation to go smoothly, efficient coordination is required among all of these mental operations and working memory has to work very efficiently.

Researchers who have used working memory as a theoretical construct in examining the mental operations in interpreting have identified working memory as a critical skill in simultaneous interpreting. Christoffels et al. (2003) examined a group of Dutch and English bilinguals untrained in interpreting and found, among other things, that working memory in the participants' L2, i.e., English, was directly related to their performance in simultaneous interpretation from English into Dutch. In comparing trained interpreters, bilingual undergraduate students, and highly proficient teachers, Christoffels et al. (2006) also found that interpreters outperformed the two other groups in terms of working memory. In both studies, the participants' working memory was assessed by having them perform a number of memory span tasks including reading span and digit span tasks, the former of which is a measure of their ability to coordinate processing and storage resources in working memory (Daneman, 1991), while the latter is a measure of storage ability. However, the participants in Christoffels et al.'s (2006) study were not asked to actually engage in simultaneous interpretation, thus the direct association between working memory and simultaneous interpretation is unknown. On the other hand, although Christoffels et al. (2003) administered a simultaneous interpretation task in addition to other tasks and found that reading span in the participants' second language (L2) was directly associated with performance in simultaneous interpretation, they did not include other groups of participants but only involved a group of regular bilinguals.

Researchers in previous studies have found that working memory capacity was not the same in a bilingual's native and second language (Chincotta & Underwood, 1998; Service, Simola, Metsänheimo, & Maury, 2002). Service et al. (2002) found that when performing a reading span task, a group of students with lower English proficiency showed differences in their L1 (Finnish) and L2 (English) reading span, with the reading span for L1 being higher than the reading span in L2. When the same reading span test was administered to students majoring in English, however, no differences were found between L1 and L2 working memory. This suggests that the effect of language may be stronger for less proficient L2 speakers than those who are more advanced users of the second language. Based on the findings of previous studies, in the present study, questions that were not fully explored regarding the role of working memory in simultaneous interpretation were explored. Also, a determination was made concerning if other factors including years of training in interpreting and language proficiency come into play.

**PURPOSE**

The aim of the present study was to examine the role that working memory plays in performance in simultaneous interpreting for both Chinese-English bilinguals untrained in interpreting and those who have received training in interpreting. A group of bilinguals without training in interpreting who spoke Chinese as their native language (L1) and English as a second language (L2) were asked to participate in this study. In addition, the study included another group of students who were undergoing training in interpreting in a two-year graduate program in translation and interpretation. Few researchers have combined student interpreters and regular bilinguals in one single study to examine the role of working memory in simultaneous interpretation performance. Therefore, I attempted to address this gap in the present study. Three major hypotheses were tested in this study:

(a) Participants who are at more advanced levels of training in interpreting will show better performance in simultaneous interpretation and will also have higher scores on the reading span and digit span tasks.

(b) For participants who are classified as equally- proficient in L1 and L2, no significant difference will be observed in working memory span tasks administered in L1 (Chinese) and L2 (English).

(c) Participants who are classified as not-equally- proficient in L1 and L2 will show higher scores in L1 than in L2 working memory span.

It was expected that the role of working memory in skill and performance in simultaneous interpretation would be more firmly established after analyzing the results from this study. Researchers in prior studies only employed bilinguals (Christoffels et al., 2003) in an attempt to form a link between working memory and simultaneous interpretation or compared interpreters' working memory with that of other bilinguals (Bajo et al., 2000; Christoffels et al., 2006) without administering an actual simultaneous interpretation task. In the present study, however, bilinguals and student interpreters engaged in both the working memory and simultaneous interpretation tasks. Although it was anticipated that larger working memory would be associated with better interpretation performance, I was also keen to explore how individuals with different proficiency in L1 and L2 would perform on the reading span and digit span tasks administered in L1 and L2.

## DEFINITION OF TERMS

**Working memory**: the ability of an individual to concurrently store and process information. The functions of the storage and processing of information compete with each other for the limited resources in working memory.

**Interpreting**: Oral transposition of a text or message delivered in a source language into a target language.

**Simultaneous interpretation**: a form of oral translation where the translator (interpreter) must listen to and comprehend the speaker's speech and produce its translation at the same time, dividing attention between comprehension and production. Simultaneous interpreters work in interpretation booths; they listen, comprehend, and speak at the same time with an input and output lag of 2-3 seconds.

**Reading span**: A concurrent memory task developed by Daneman and Carpenter (1980) to measure an individual's working memory. During the test, participants read sets of unrelated sentences that increase in set sizes in one or multiple languages. At the end of the set they will attempt to recall the final word of each sentence.

**Digit span**: A measure of short-term memory that consists of asking participants to listen to single digits (0-9) that are presented in random order and repeat aloud what they hear.

# CHAPTER II

# LITERATURE REVIEW

In this chapter, the task of simultaneous interpretation will be described in terms of the complex cognitive processes and the difficulties involved in the task. A discussion regarding how bilinguals and simultaneous interpreters control their two languages will follow. The different theoretical frameworks used in analyzing simultaneous interpretation in past studies will then be reviewed with special focus placed on working memory. In the final two sections of this chapter, recent studies that are most relevant to the present study will be highlighted and the gaps or deficiencies of these past studies, which were addressed in my study, will be discussed.

## THE PHENOMENON OF SIMULTANEOUS INTERPRETATION

Simultaneous interpretation is regarded as one of the most difficult language processing tasks (Frauenfelder & Schriefers, 1997). Unlike in translation, where the translator can, often without time constraint, consult a dictionary or other materials in order to transform information in the source language into the target language, the simultaneous interpreter is required to comprehend, process, and store the source language message while at the same time produce output in another language, i.e., the target language. Added to this is the fact that all of these processes have to be completed under severe time constraints. The difficulty involved in simultaneous interpretation is further demonstrated by the sometimes less-than-perfect performance on the part of interpreters. It is widely recognized that even the performances of experienced professional interpreters suffer on some occasions and that errors, omissions, and other flaws in output are unavoidable (Barik, 1994; Gile, 1997). This raises the issue of limited processing and storage capacity to which I will return in the following sections.

## SOURCES OF DIFFICULTY IN SIMULTANEOUS INTERPREATION

### Concurrent Listening and Speaking

A major source of difficulty in simultaneous interpreting is the simultaneity of comprehension and production (Bajo et al., 2000; Christoffels & De Groot, 2004, 2005). According to Chernov (1994), when the interpreter is on task s/he has to concurrently listen and speak 70% of the time although the interpreter can take advantage of natural pauses in the input speech (Barik, 1973). The interpreter not only needs to comprehend the input of the message delivered in one language and temporarily store it in memory while processing continuously incoming new messages, previously stored information has to be retrieved and reformulated into another language. Having to deal with listening and speaking in two languages at the same time also means that interpreters have to be able to have perfect control over the two languages (Christoffels & De Groot, 2005; Gile, 1997) and not, for example, interpret into the non-target language.

### Input Speech Rate and Density

The rate at which the source language speech is delivered has a decisive impact on performance in simultaneous interpreting. An input rate of 100-120 wpm (words per minute) is considered acceptable for interpreters, with 150-200 wpm as an upper limit (Gerver, 1976). On the other hand, for recited text which has high information density, Lederer (1981) suggested an input rate of 100 wpm as a maximum. Barik (1973) found that the faster the source speech rate, the more flaws were observed in the interpreters' output and the longer they lagged behind the speaker. Although faster input speech rate is generally believed to have a detrimental effect on interpreting, there are exceptions where slow speech rates were shown to have more negative effects on output. Slow, monotonous delivery of the input speech can be difficult, if not more difficult than messages that are delivered with a faster rate (Gerver, 1976).

Some professional interpreters are more concerned about density of the input message than the rate of speech delivery (Setton, 1999). Simultaneous interpreters often find it extremely challenging to interpret for a speaker who reads from a dense written text which is delivered at a high speed. Treisman (1965), for example, found that the accuracy of interpreter's performance suffered with increasing information density in the source speech. Chernov (1994) also noted that redundancy in speech as opposed to non-redundant speech such as poetry or legal papers can facilitate interpretation performance because the former allows the interpreter to anticipate subsequent input.

**Characteristics of Source Text**

Characteristics of the source language input such as difficulty of texts, whether the texts are more spontaneous or structured, and the difference of language structure between the source language and target language can potentially affect interpretation performance. Differences in word order and syntactic structure between the source language have been found to impose difficulty for interpreters working from Chinese into English and from German into English (Setton, 1999).

Another source of difficulty in simultaneous interpretation arises from the difficulty of the source text. Darò, Lambert, and Fabbro (1996) found that when the source text contained more low-frequency words and had sentence structures which were more complex, more errors were detected in the target language output than when the source text was easy. Single words in the source language text may also pose problems for the simultaneous interpreter. Abstract words that may have different meanings in the target language (Barik, 1975) as well as words with greater word length (Christoffels & De Groot, 2005) can potentially decrease the quality in the interpretation output.

## BILINGUAL LANGUAGE CONTROL

Bilinguals are generally defined as people who can use two languages and engage in all or some of the comprehension and production tasks involving these two languages. Since all interpreters are bilinguals or even multilinguals, a brief discussion on some scholars' views about how they keep their languages separate, i.e., how they control their languages and avoid "switching" to the non-target language will follow.

In describing how bilinguals exert control over their speech, Green (1986, 1998) proposed the Inhibitory Control Model. According to this model, language selection is achieved by inhibiting candidates in the nontarget language which in turn requires monitoring and control by a supervisory attentional system (SAS). Green (1998) stated that so called language task schemas “regulate the outputs from the lexico-semantic system by altering the activation levels of representations within that system and by inhibiting outputs from the system” (p. 69). As such, based on Green’s model, two types of language control operate in bilingual language processing: one acts proactively by adapting the levels of activation of the L1 and L2 items to the demands of the specific task; a second operates reactively by suppressing non-target language output (Green, 1986). Green’s Inhibitory Control Model assumed separate language subsystems for a bilingual’s two languages just as Dijkstra and Van Heuven (1998, 2002) also proposed a Bilingual Interactive Activation (BIA) model in which the two languages of the bilingual are represented by two separate language nodes. The two language nodes are capable of receiving activation from lexical items in the other language and this in turn triggers excitary connections between words of the two languages and the corresponding language nodes.

Meuter and Allport (1999), meanwhile, used switch tasks in their study to explore how bilinguals control their languages. When the participants (unbalanced bilinguals) in their study were asked to perform tasks that required switching between the easy, dominant task (L1 numeral naming) and the more difficult, weaker task (L2 numeral naming), it appeared that a switch from the more difficult to the easy task incurred a greater switching cost reflected by longer response latencies. Meuter and Allport explained the “counterintuitive” results by citing a phenomenon called “task set inertia”.

An individual engaged in a switch task encounters a task set inertia when the task set of the previous trial carries over into the current trial, so that when s/he performs a task switch from L2 numeral naming (weaker task) to L1 numeral naming (dominant task), the strong suppression of the dominant task in the previous trial affects the performance in the current trial and results in longer reaction time (greater cost) for the L1 numeral naming task (Allport, Styles, & Hsieh, 1994). The results suggest that bilingual language production involves the suppression of the non-target language and the activation of the target language and that the stronger or more proficient the non-target language, the larger the cost associated with suppressing it.

Bialystok, Craik, Klein, and Viswanathan's (2004) research went further to show that the advantage of bilingualism extends to areas beyond language control superiority as evidenced by their study's bilingual participants who outperformed other monolinguals in a task called the "Simon task." Simon task is used to assess a participant's ability to ignore irrelevant spatial information and is intended to measure one's effectiveness in inhibitory processes. The bilinguals in Bialystok et al.'s (2004) study not only were found to have better inhibitory control (smaller "Simon effect") than the other monolinguals, they also showed a smaller increase of the Simon effect with aging. Another unexpected finding in their study was that bilingualism also had a positive effect on working memory for the older bilingual adults, showing that bilingualism can offset the negative impacts of aging on working memory.

Extending the view of how regular bilinguals control their two languages, Paradis (1994) attempted to explore how simultaneous interpreters regulate the source and target languages. Because in simultaneous interpretation, comprehension of the source language and production of the target language co-occur most of the time, Paradis (1994) suggested that both language systems are activated at the same time, though the threshold of elements in the source language is set higher so that only the target language is spoken. This view, however, was problematic in that lower activation of the source language meant that comprehension of the source language would be compromised, which may lead to less-than-perfect performance in simultaneous interpreting (Tommola, Laine, Sunnari, & Rinne, 2000/2001).

An alternative view was proposed by Grosjean (2001) who added input and output processing mechanisms to both language systems. The two language systems were not differentially activated, according to Grosjean, but the output mechanism of the source language is inhibited while the input mechanism of the source language is activated. In addition, both the input and output processing mechanisms of the target language are activated. The input mechanism of the target language is also activated for reasons that interpreters monitor their speech during simultaneous interpreting (Isham, 2000). Both Paradis (1994) and Grosjean's (2001) proposals assume the activation or deactivation of language whole or subsystems.

La Heij's (2005) "complex access, simple selection" is perhaps the least complex of all. La Heij suggested that the preverbal message must not be affected by the language of an input and that output in the intended language will emerge if the preverbal message correctly specifies the target language. This view is an extension of the theory of vertical or conceptually mediated translation (Christoffels & De Groot, 2005) in which the "non-linguistic" meaning is seen as the crucial connection between source and target language. The language cue is the vital piece of information in La Heij's language control model which guarantees that output in the target language, rather than words in the source language, will be produced.

## THEORETICAL MODELS OF INTERPRETING

### Gile's Effort Model

As discussed in previous sections, the difficulty posed by simultaneous interpreting is evidenced by the fact that even experienced interpreters produce errors when interpreting. It shows that there is an intrinsic difficulty in interpreting and Gile's (1995) Effort Model for simultaneous interpretation sought to capture this difficulty. The basic notion underlying this model is that the interpreter's processing capacity is limited, thus when the processing demands exceed processing capacity, interpretation performance will deteriorate.

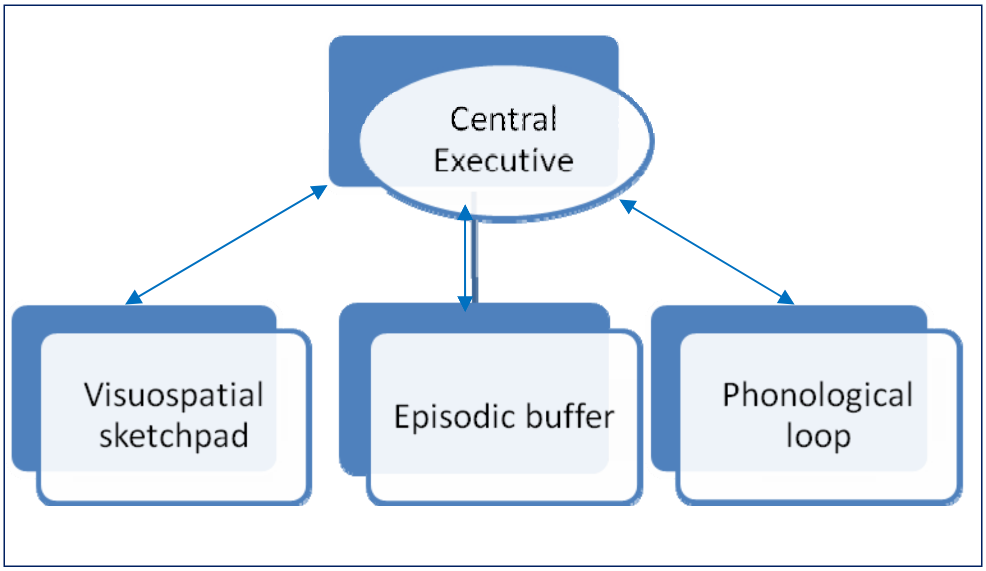
Based on his observation of simultaneous interpretation, Gile modeled simultaneous interpretation as consisting of three major *Efforts*: *the listening and analysis effort, speech production effort, and short-term memory effort*. A fourth component of the model is the coordination effort (Eysenck & Keane, 1990). The three major effort components are thought of as being active at the same time while each possesses limited capacity. Depending on the tasks involved, each effort is given specific processing capacity requirements. Further, because the incoming speech flow varies widely and each interpreter segments processing units differently, processing capacity requirements for each effort may vary to a great extent over a matter of just a few seconds. For the interpretation to proceed smoothly, at any given point during interpretation, the capacity required for each of the four efforts must be tantamount to or greater than its requirements for the task at hand (Gile, 1997).

Gile (1995) noted that processing capacity requirements for each effort sometimes are further burdened by interaction between the individual requirements for the separate efforts. Interference from source language to target language is one instance, which is why the interpreters are often taught to make every effort to not use words and sentence structures that resemble those in the source language speech (Gile, 1995).

## Baddeley's Working Memory Model

Baddeley developed one of the most influential models of working memory (Baddeley, 1986; Baddeley & Hitch, 1974). Working memory, based on this model, is composed of three subsystems: a) the *central executive*, b) the *phonological loop*, and 3) the *visuospatial sketchpad*. Baddeley (2000) added a fourth component, the *episodic buffer*, which is assumed to be capable of "storing information in a multi-dimensional code" (p. 421) and serves as an interface between long-term memory and the *phonological loop* and *visuospatial sketchpad.* As shown in Figure 1, the *central executive* coordinates the processes of the *episodic buffer* and two other subsidiary slave systems and acts as an attentional control mechanism. The *visuospatial sketchpad* processes visual images while the *phonological loop* is responsible for storing verbally coded information and is therefore most relevant for simultaneous interpretation. The *central executive* is involved in "general" processing but does not have storage capacity, but this gap was filled by the addition of *episodic buffer* to Baddeley's (2000) working memory model.

Figure 1. Baddeley's working memory model




*Note.* Baddeley (2000)

According to Baddeley (2000), the *phonological store* and the *subvocal rehearsal* process are the two subparts of phonological loop. The *phonological store* temporarily holds acoustically perceived verbal information that quickly decays after about 1.5 to 2 seconds unless the information gets refreshed by the *subvocal rehearsa*l process. Memory traces of verbally coded messages are fed back into the articulatory control processes through *subvocal rehearsal*, thereby prolonging their presence within the working memory.

Studies examining the relation between working memory and simultaneous interpretation have found that when participants were subjected to articulatory suppression, i.e., when they were asked to perform recall tasks and utter a string of irrelevant syllables or words, the interpreters outperformed the other groups (e.g. Bajo et al., 2000; Padilla, Bajo, Cañas, & Padilla, 1995; Padilla, Bajo, & Macizo, 2005). The condition of articulatory suppression poses difficulty in verbal recall tasks mainly because it disrupts the process of *subvocal rehearsal* that is necessary for refreshing verbal information and maintaining the information in the *phonological store* (Baddeley, 1996). Since the articulation of output material in simultaneous interpretation resembles articulatory suppression (Padilla et al., 2005), simultaneous interpreters are viewed as being more resistant to its negative effects and are consequently considered to have a larger working memory.

**Just and Carpenter’s Theory of Working Memory Capacity**

Based on Baddeley’s (1981, 1986) working memory model in which he emphasized the processing and temporary storage functions of this system, Just and Carpenter (1992) developed the working memory capacity model. According to Miyake, Just, and Carpenter (1994), working memory is capable of both processing and storing information and is considered to be the site for both carrying out various language processes and holding intermediate and/or final products of comprehension. The processing and storage functions of the working memory compete for a shared limited capacity, and the ability to process and store information simultaneously is often used to distinguish skilled and unskilled speakers (Daneman, 1991).

Although being of limited capacity, working memory is not the same between two individuals. Those who are more “efficient” in executing the cognitive tasks at hand are regarded as having a larger working memory capacity. A good reader, for example, may need fewer processes than the poor reader to process the same material and therefore be considered more efficient as well as possessing a larger working memory capacity (Daneman & Carpenter, 1980). Working memory also plays an important role in verbal fluency (Daneman & Green, 1986) and can be used as an index for choosing or training individuals in professions that require a lot of speaking such as simultaneous interpretation. In ordinary speaking, all speakers have to plan what to say, temporarily store the plans, and finally implement them in the form of words or sentences. As such, speakers who have small working memory capacities have been found to be slower and less fluent at producing words, sentences, and phrases that are context-appropriate than speakers who have larger working memory capacities (Daneman, 1991).

In simultaneous interpretation, the interpreter is continuously engaged in online processing and storing of information and having a large working memory capacity is therefore crucial (e.g., Christoffels et al., 2003; Christoffels et al., 2006). The reading span test developed by Daneman and Carpenter (1980) is frequently used as a measure to assess or predict an individual’s performance in tasks that involve concurrent processing and storage of information such as language comprehension. In the reading span test, participants read sentences that increase in set sizes and recall sentence-final words. The total number of successfully recalled words (e.g., Daneman, 1991) or the largest set size in which the majority of the sentence-final words are recalled (e.g., Daneman & Carpenter, 1980) represents the participants' working memory capacity.

## WORKING MEMORY AND SIMULTANEOUS INTERPRETATION - REVIEW OF RESEARCH

In the following section(s), I will first review studies that compare participants' recall of language items after simultaneous interpreting and after other tasks in order to show how memory is differentially affected by these tasks. Next, I will focus on studies that examine, among other things, the relation between working memory and performance in simultaneous interpretation.

### The Negative Effects of Concurrent Articulation on Recall

The fact that simultaneous interpreting is taxing to working memory has been evidenced by numerous studies. Both Darò and Fabbro (1994) and Isham's (2000) studies found that having to listen to words, digits, or narratives while at the same time recall them presented the greatest difficulty compared to other conditions. In Darò and Fabbro's (1994) study, students who were at the advanced level in an interpreting training program were given two tasks. In one, they were asked to recall short narratives verbatim after either listening to or simultaneously interpreting the narratives. In the second task, the interpreting students recalled a series of digit lists of varying lengths under four conditions: listening, shadowing, simultaneous interpreting, and concurrent articulation. Shadowing involved within language repeating of digits that were auditorily presented to participants while concurrent articulation required that the participants utter irrelevant syllables when listening to the digits. Participants' performance was found to be the worst when they were asked to recall narratives and digits after simultaneously interpreting them into the target language. One intriguing finding of this study was that even for a simple task such as translation of single digits, simultaneous interpretation was still found to cause the most interference in recall.

Similarly, though Isham (2000) included only non-interpreters in his study and did not administer a simultaneous interpreting task, the concurrent articulation condition also posed the highest challenge in the verbatim recall task. The concurrent articulation is thought to resemble the task of simultaneous interpretation. The two other conditions in Isham's study were pure listening and dichotomous listening; the latter was done by having participants listen to speech in one ear and pre-recorded voice saying an irrelevant word "double" in the other.

As discussed in the previous section on Baddeley's working memory model, to prolong memory of the verbal information in the *phonological store*, the information has to be rehearsed subvocally. Under the concurrent articulation or articulatory suppression and simultaneous interpreting conditions, the participants' vocal tracts were engaged while listening to speech materials that were to be recalled later hence their performance was impaired.

Christoffels and De Groot (2004) compared recall of sentences after interpreting, shadowing, and paraphrasing them in simultaneous and delayed conditions for a group of Dutch-English bilinguals. In the delayed condition, the participants interpreted, shadowed, or paraphrased sentences only after each sentence was completely presented to them. Even though in the simultaneous condition, performance of recall was not found to be different among the three tasks, across tasks recall in the simultaneous condition was significantly poorer than in the delayed condition. The results of this study once again highlighted the detrimental impact of concurrent listening and speaking on recall.

## Working Memory and Other Cognitive Skills in Simultaneous Interpretation

Only in the recent decade have some researchers begun to explore the various cognitive subskills involved in simultaneous interpretation. In four recent studies, as summarized in Table 1, researchers used a number of tasks to determine what skills are most relevant to simultaneous interpretation. In three of the four studies, the authors have pointed out the critical role that working memory plays in simultaneous interpretation.

The studies reviewed in Table 1 (Bajo et al., 2000; Christoffels et al., 2003; Padilla et al., 2005; Christoffels et al., 2006) used various measures that are deemed capable of eliciting the relevant skills in simultaneous interpretation. With the exception of Christoffels et al.’s (2003) study, all of them compared professional interpreters’ performance to those of bilinguals, student interpreters, or professionals in other field. The rationale behind these studies was that interpreters have at their disposal a number of cognitive skills which are used either more efficiently or are at higher levels than the other groups. As such, all the tasks administered in these studies were meant to tap into these skills and some examples are the picture naming and word translation tasks for measuring lexical retrieval and reading span and digit span for assessing working memory capacity.

Table 1. Summary table for studies that examine the cognitive subskills of SI

| **Author(s)** | **Participants** | **Tasks and Procedures** | **Major Findings and Areas of Concern** |
|---|---|---|---|
| Bajo, Padilla, & Padilla (2000) | 1. Professional Interpreters<br>2. Bilinguals<br>3. Student Interpreters<br>4. Professionals from other field | Linguistic Ability:<br>1. Moving Window<br>2. Lexical Decision<br>3. Word Categorization<br><br>Working Memory Capacity:<br>4. Digit Span<br>5. Phrase Span<br>6. Articulatory Suppression<br><br>Results for group comparison on Digit span:<br>$F(2,27) = 3.26$, $p= .05$, $\omega^2 = .13$<br><br>Phrase span: | - Interpreters read with greater speed without compromising understanding.<br>- Interpreters superior in lexical decision, word categorization, and working memory<br>- Interpreters' skills are trainable based on student interpreters' performance.<br>- Interpreters performed best under articulatory suppression.<br>**Efficiency in comprehension in** |

Table 1 Continued

| **Author(s)** | **Participants** | **Tasks and Procedures** | **Major Findings and Areas of Concern** |
|---|---|---|---|
| Bajo, Padilla, & Padilla (2000) continued | | $F(2,27) = 5.32$, $p<.01$, $\omega^2 = .22$. | **interpreter is due to better management of working memory resources.** |
| Christoffels, De Groot, & Waldorp (2003) | 1. Bilinguals untrained in interpreting | Memory:<br>1. Reading Span<br>2. Verbal Digit Span (only in native language)<br><br>Lexical retrieval:<br>3. Picture Naming<br>4. Word Translation<br>5. Simultaneous Interpretation Task into L1 (4.2 min-long speech) | -Word translation efficiency and working memory are "independent" subskills of SI performance.<br>- Reading span in L2 ($r = .44$, $p<.05$) and translation into L2 are directly related to SI performance.<br>Major Concern: No comparison group. |
| Padilla, Bajo, & Macizo (2005) | 1. Interpreters<br>2. High memory span psychology students<br>3. Professionals in other fields who are not | Experiment 1: Recall under silent and articulatory suppression conditions. | Experiment 1: Interpreters' performance not affected by articulatory suppression, so WM does not explain their ability |

Table 1 Continued

| **Author(s)** | **Participants** | **Tasks and Procedures** | **Major Findings and Areas of Concern** |
|---|---|---|---|
| Padilla, Bajo, & Macizo (2005) continued | bilinguals (1,2, and 3 included in Experiments 1& 2)<br>4. Professional interpreters (Experiment 3) | Experiment 2: Recall words under normal and visual tracking conditions.<br><br>Experiment 3: Interpreters studied and recalled words in L1, L2 or non-words in articulatory suppression and normal conditions. | to comprehend and produce simultaneously.<br><br>Experiment 2: No difference among three groups.<br><br>Experiment 3: Articulatory suppression effect absent when interpreters studied words in L1, present but non-significant when studying L2.<br><br>**Having a large WM may be a necessary condition for good SI performance, but long term knowledge may be more important.** |

Table 1 Continued

| **Author(s)** | **Participants** | **Tasks and Procedures** | **Major Findings and Areas of Concern** |
|---|---|---|---|
| Christoffels, De Groot, & Kroll (2006) | 1. Interpreters vs. bilingual undergraduates (Experiment 1)<br><br>2. Interpreters vs. highly proficient English teachers (Experiment 2) | Working memory:<br>1. Word Span<br>2. Reading Span<br>3. Speaking Span<br>Results for group comparison in Exp. 1:<br>Reading span: $F(1,50) = 4.76$, $p = .03$, $\omega^2 = .04$<br>Speaking span: $F(1,50) = 16.23$, $p < .001$, $\omega^2 = .13$<br>Word span: $F(1,50) = 14.66$, $p < .001$, $\omega^2 = .12$<br>Exp. 2:<br>Reading span: $F(1,26) = 10.92$, $p < .01$, $\omega^2 = .15$<br>Speaking span: $F(1,26) = 13.81$, $p < .01$, $\omega^2 = .19$<br>Word Span: $F(1,26) = 13.32$, $p < .001$, $\omega^2 = .18$ | Experiment 1: Interpreters show superior performance in language processing and memory than bilinguals.<br><br>Experiment 2: Interpreters show better performance in memory only. |

Table 1 Continued

| **Author(s)** | **Participants** | **Tasks and Procedures** | **Major Findings and Areas of Concern** |
|---|---|---|---|
| Christoffels, De Groot, & Kroll (2006) continued | | Lexical Retrieval:<br>4. Picture Naming<br>5. Single Word Translation<br>Control Tasks:<br>6. English Vocabulary Test<br>7. Non-linguistic reaction time test | **Working Memory is a critical subskill in SI.**<br>Concern: No SI task |

*Note.* Effect sizes for results related to working memory measures were reported as omega squared, $\omega^2$ , which is a population effect size.

In Bajo et al.'s (2000) study, the main conclusion that is of particular relevance to the present study is that interpreters are more efficient at managing their working memory than non-interpreters. When comparing student interpreters' performance on the comprehension (moving window), word categorization, and lexical decision tasks at the beginning of the academic year with that at the end of the academic year, Bajo and colleagues found their performance improved. The same comparison, however, was not conducted for the reading and digit spans or the recall with or without articulatory suppression tasks. As such, Bajo et al. (2000) did not establish whether working memory is susceptible to training.

In an earlier study by Padilla et al. (1995), tasks of memory span were also used to assess four groups of participants: interpreters, non-interpreters, second-year student interpreters, and third-year student interpreters. Although one of the purposes of the study was to determine the effect of training on working memory, the effect of training was only found between professional interpreter and other groups rather than between the second-year and third-year student interpreters. Therefore, whether student interpreters at different levels of interpreter training show differences in working memory capacity warrants further research.

Christoffels et al. (2003, 2006) used virtually the same set of tasks in their studies and concluded that working memory is a crucial subskill in interpreting. The key difference between the two studies was that Christoffels et al. (2003) did not employ comparison groups in their study despite the fact that they had an actual simultaneous interpretation task in their experiment. They found that having had no training whatsoever in interpreting did not present a huge obstacle for the non-interpreters in their study; in fact, they may even be an ideal group for study because interpreters often use idiosyncratic strategies (Shlesinger, 1994). Thus, for the purpose of selecting student interpreters for training, results from studies that examine the “natural ability” of bilinguals untrained in interpreting may be more informative.

Moreover, working memory may interact with language proficiency as evidenced in the different L1 and L2 working memory exhibited by the bilinguals in the Christoffels et al.’s study (2003). They found their bilingual participants’ reading span in L2 (English) to be directly associated with their performance in simultaneous interpreting into Dutch

(L1). In other words, it was working memory capacity in a not completely automated language that determined performance in simultaneous interpretation. The language effect in working memory was also identified by Service et al. (2002), with the more proficient speakers of L2 showing no difference in L1 and L2 working memory and the less proficient L2 speakers having lower working memory in L2. Christoffels et al. (2006), however, found an advantage even in L1 working memory for the interpreters, thus whether working memory in both L1 and L2 predict performance in simultaneous interpreting is something worth exploring.

Padilla et al. (2005) adopted measures that were quite different from the other three studies (reviewed in Table 1). Reading span as a measure of working memory was not used as a task *per se* in the study but having a high score on the reading span was the criteria for a group of psychology students selected to participate in the study. The fact that interpreters rather than the high-memory span students performed better in recall under articulatory suppression led Padilla and colleagues to reach the conclusion that working memory is not the most important skill in simultaneous interpreting. They argued that an individual’s long term word-knowledge may provide more support for simultaneous interpretation. Still, although articulatory suppression may resemble what simultaneous interpreters do on task – listening and speaking at the same time – it does not mirror simultaneous interpretation. Without actually asking participants to “interpret”, claims about the importance of working memory in simultaneous interpreting cannot be made. Results from three out of four of the studies reviewed above lend support to the importance of working memory in performing the job of simultaneous interpreting.

Using the novice-expert paradigm, two studies (Köpke & Nespoulous, 2006; Liu et al., 2004) involving professional interpreters and novice interpreters found otherwise. Rather than using the traditional reading span measure, both studies adopted an auditory version of the reading span, whereby participants listened to the sentences and memorized the last word of each sentence. In addition, Köpke and Nespoulous (2006) also used a wide variation of other memory measures (e.g. different versions of word span, digit span, etc.). The results of both studies, however, did not find the professional interpreters to have a larger working memory. In Köpke and Nespoulous' (2006) study, the novice interpreters outperformed the professional interpreters in all working memory tasks. Liu et al. (2004) also found that novice and professional interpreters who had the same working memory capacity nevertheless performed differently in simultaneous interpretation, with professional interpreters generally outperforming student interpreters. They believed that working memory should be conceptualized as a "general" cognitive ability that cannot serve to explain the performance gap in interpretation between professional vs. novice interpreters.

## CHAPTER SUMMARY

In this chapter, I have first described the phenomenon of simultaneous interpretation and discussed why it is a challenging feat by listing sources of difficulty involved in the process of simultaneous interpretation. Having to listen and comprehend in one language and produce output in another language may be the most difficult challenge that simultaneous interpreters need to deal with. The rate of source text delivery, density of text, and other characteristics of the source text are all potential factors that may affect the performance of the interpreter.

Interpreters, as bilinguals, have learned to control their languages through extensive experience with using two languages. Thus, I have devoted a section to discussing the views of various researchers regarding how bilinguals and simultaneous interpreters execute language control. Dijkstra and Van Heuven (1998), Green (1986, 1998), and Meuter and Allport (1999) all suggested that there are separate subsystems for bilinguals' two languages and that in order for bilinguals to produce in one language, s/he has to activate that language and suppress the other.

Views regarding how simultaneous interpreters control their source and target languages suggested the activation or inhibition of whole or sub- language systems (Grosjean 2001; Paradis, 1994). These proposals, however, are more complex than La Heij's (2005) language control model which assumes that output in the target language can be achieved as long as the preverbal message is correct and the language cue is present.

The different theoretical models frequently adopted in interpretation research and reviewed above included Gile's (1997) Effort Model, Baddeley's (1986, 2000) working memory model, and Just and Carpenter's (1992) theory of working memory capacity. Of particular relevance to the present study is Just and Carpenter's working memory capacity model. Working memory capacity is defined as the ability of an individual to process and store information at the same time. As mentioned in previous sections, the reading span test developed by Daneman and Carpenter (1980) has often been used as a measure for assessing an individual working memory capacity. Having an efficient working memory, as found in several studies, is associated with good speaking skills (Daneman, 1991), verbal fluency (Daneman & Green, 1986), and performance in simultaneous interpreting (Bajo et al., 2000; Christoffels et al., 2003; Christoffels et al., 2006).

The studies reviewed above seem to agree that working memory, among other cognitive skills involved in simultaneous interpretation, assumes an important role in simultaneous interpretation performance. The main difference observed in these studies were the use of different participant groups, and with the exception of Padilla et al.'s (2005) study, all other studies (as summarized in Table 1) adopted measures that tapped into the participants' working memory and linguistic or lexical retrieval ability.

Since the present study focused on the relevance of working memory in simultaneous interpreting, I only addressed how these different studies had dealt with the role of working memory in simultaneous interpretation. The authors of these studies claimed that they found an association between working memory and performance in simultaneous interpreting, however, only one of the studies (Christoffels et al., 2003) actually administered a simultaneous interpretation task with the participants. The other three studies merely compared the working memory of interpreters in training or professional interpreters with that of other bilinguals and professionals in other fields who were not bilinguals. Based on the higher working memory exhibited by the interpreters, these studies (except for Padilla et al.'s study) concluded that working memory is a critical skill in simultaneous interpreting. However, without having the participants carry out a simultaneous interpretation task, conclusive claims about the association between working memory and performance in simultaneous interpretation cannot be established. Therefore, the present study sought to address this gap by including an actual simultaneous interpretation task. Moreover, researchers in most of these studies did not specifically identify whether or how they made attempts to establish the participants' language proficiency in L1 and L2. The only attempt at evaluating levels of language proficiency was a language background questionnaire used by Christoffels et al. (2003, 2006), in which participants were asked to self-rate their English (L2) proficiency without asking them to also assess their native language command. The absence of a more objective baseline measure for evaluating participants' language proficiency in both L1 and L2 demonstrates that the difference among participants in various tasks in these past studies may very well be attributable to different levels of language proficiency rather than difference in working memory. Further, the question regarding whether working memory is trainable was not fully explored in past studies, hence the present study examined whether working memory can be trained by comparing the working memory capacity of student interpreters at different levels of training.

On the other hand, though Köpke and Nespoulous (2006) and Liu et al. (2004) have found in their studies comparing interpreters with many years of professional training vs. those who were still being trained that working memory seemed to play a lesser role in simultaneous interpretation, they did not investigate whether this "general" (Liu et al., 2004) cognitive skill can be a criteria for selecting the best candidates to be trained to become professional interpreters. It was thus the aim of this study to examine if regular bilinguals differ from those aspiring to become professional interpreters in the general cognitive skill of working memory and whether regular bilinguals with larger working memory capacity also tend to have better performance in simultaneous interpretation. In sum, in an effort to extend research done in previous studies on the relation between working memory and simultaneous interpretation and address gaps unfulfilled in these studies, the present study sought answers for the following research questions:

(a) Do individuals who differ in terms of SI training differ in terms of:

- reading span in L1 and L2
- digit span in L1 and L2
- simultaneous interpretation performance

(b) What is the relationship between working memory span and simultaneous interpretation performance?

(c) Do individuals who are classified as equally-proficient in L1 and L2 differ in terms of L1 and L2 working memory span?

(d) Do individuals who are classified as not- equally- proficient in L1 and L2 exhibit more working memory for L1 than L2?

# CHAPTER III

# METHOD

In this chapter, how the present study was conducted will be discussed. In particular, the chapter will begin with an introduction of the participants involved in this study with specific details on how they were selected. A description of the materials used in this study and the procedures of the implementation of the study will follow. Finally, the chapter will end with a discussion of the design of the study.

## PARTICIPANTS

The participants in this study were 36 Chinese-English bilinguals, among whom 20 were undergoing training in interpreting in a graduate school in California. Eleven of them were, at the time of the experiments, approaching the end of their first year training in the program whereas nine of them were reaching the end of second year of interpreter training. In addition, this study included 16 Chinese-English bilinguals, most of whom were graduate students attending two different universities in the US majoring in different fields of study. The participants' biographical data are summarized in Table 2. The 16 bilinguals are referred to as the "bilingual" group while the 20 participants undergoing interpreter training belong to the "student interpreter" group and were further categorized as first- and second-year student interpreters. All participants in the bilingual group spoke Chinese as their first language (L1) and English as their second language (L2). This was also true for all of the participants in the student interpreter group. The participants were paid for their participation in this study.

Across the three groups, more than half were born in Taiwan while the rest of the participants were born in China. In terms of gender, females were the majority; among the first-year student interpreters, all were females. Mean age, length of stay in the US, and TOEFL scores for participants from each group are displayed in Table 2. It should be noted that some of the participants (one from each group) did not report TOEFL scores, so the calculation of mean TOEFL scores was based on those who reported their scores. A comparison of the three group's TOEFL scores showed that the bilinguals had a large variability in their TOEFL scores (SD = 55.84), whereas the student interpreters' range of TOEFL scores were smaller. Although a TOEFL score of at least 600[2] was one of the requirements for admission to their graduate school for the first- and second- year student interpreters, two of them did not have to furnish proof of TOEFL (as specified in the language requirements section of the school's admission website) and one submitted an IELTS[3] score of 8. According to the graduate school's admission guidelines, submission of IELTS scores was an alternative for those who did not take TOEFL. A minimum IELTS score of 7 was required.

[2] Three versions of TOEFL were available when the study was conducted: the traditional paper version, computer test, and the internet test. For ease of comparison, scores of participants who took the TOEFL test in the latter two versions were converted into comparable paper version scores.

[3] IELTS is the International English Language Testing System. It is a test of English language proficiency and is accepted by most Australian, British, Canadian, Irish, New Zealand and South African academic institutions, and now by an increasing number of academic institutions in the USA.

Table 2. Biographical information of participants

| | Group | | |
|---|---|---|---|
| | **Bilinguals (n= 16)** | **1st year student interpreters (n = 11)** | **2nd year student interpreters (n= 9)** |
| Country of Birth | Number | Number | Number |
| Taiwan | 9 (56%) | 6 (55%) | 5 (56%) |
| China | 7 (44%) | 5 (45%) | 4 (44%) |
| Gender | | | |
| Female | 12 (75%) | 11 (100%) | 8 (89%) |
| Male | 4 (25%) | 0 | 1 (11%) |
| | Mean | Mean | Mean |
| Age | 28.44 (3.67) | 25.73 (4.5) | 30.22 (5.63) |
| Length of Stay in the US (months) | 34.78 (28.16) | 30.36 (34.84) | 38.67 (45.65) |
| TOEFL Score | 587.47 (55.84) | 636.33 (11.11) | 644.5(7.45) |

*Note*. The numbers in parentheses for the means indicate standard deviations.

As one of the purposes of this study was to examine the possible role that interpreter training plays in working memory enhancement, the student interpreter group included both first-year and second-year students in the aforementioned graduate school which offered two-year interpreter and translator training in several language combinations such as Chinese-English, French-English, and Russian-English. The 20 students were recruited from the Chinese-English program and were contacted through the Dean of that graduate school. In addition, an initial meeting was made with the student interpreters during their regular classes and a sign-up sheet was distributed to students who expressed interest to participate in the study. As for the participants in the bilingual group, emails were sent to potential candidates and the 16 bilinguals were the ones who responded with an interest to take part in the study.

## MATERIALS

There were four major instruments/tasks used in this study: (a) working memory measures including L1 and L2 digit span and reading span, (b) an online phrase translation task aimed at measuring language proficiency in L1 and L2, (c) a simultaneous interpretation task, and (d) a language background questionnaire.

The working memory measures were administered in participants' L1 and L2 – Chinese and English. As in previous studies (Bajo et al., 2000; Christoffels et al., 2003) using the digit span, single digits from 0-9 were chosen through an online random number generator (Daniels, 2003). The digits were organized in sets of increasing digit sizes, and pre-recorded on an audio cassette (Appendix A). The maximum number of digits to be recalled was set at ten.

The reading span task was also administered in both Chinese and English. Based on the reading span test developed by Daneman and Carpenter (1980), a total of 42 English and Chinese sentences with lengths ranging from 13-17 words were used for the study (Appendices B and C). A portion of the 42 sentences were picked from a prior working memory-related study (Liu, 2001) and the remaining sentences were selected from various Chinese and English texts, all of which were written by native speakers. The sentences contained no technical terms and were simple in structure and content.

A phrase translation judgment task was used as one of the indices of each participant's proficiency in English and Chinese[4] and the task was developed with E-Prime, a software application used in psychological and neuroscience research with a timing accuracy to the millisecond precision level. The stimuli used for this task were 20 Chinese and 20 English short idiomatic phrases that were roughly equivalent in word lengths. The Chinese phrases and their English translations were mainly selected from two books on Chinese Idioms (Situ, 2002). For example, two of the English phrases in this task were "*don't bite off more than you can chew*" and "*don't overestimate your own ability*". While both phrases have the same meaning, the former is a figurative translation while the latter is a literal translation of the Chinese phrase, *切勿不自量力*. It should be noted that only time spent on reading the first phrase, rather than the second phrase, was used as the index for language proficiency. If the Chinese phrase appeared as the first phrase, the time each participant spent on reading the phrase would be counted towards reading time for Chinese. On the other hand, if the English phrase appeared as the first phrase, the time reading the phrase would be taken as reading time for English. Research on reading has shown that reading of single sentences in second language is slower than

[4] The translation judgment task had another aim - to examine participants' preferred translation strategy. They saw literal vs. figurative translations of the first phrases they had read and had to decide if the second phrase was the first phrase's translation.

first language (Frenck-Mestre, 2002; Hoover & Dwivedi, 1998), thus it was assumed that participants would spend less time when reading a stimulus phrase presented in their more proficient than less proficient language. Therefore, reading times (milliseconds) in L1 and L2 served as one index for proficiency in the two languages.

The stimulus material chosen for the simultaneous interpretation task was taken from a transcript of a portion of a speech originally delivered by former U.S. president Bill Clinton at the Taiwan Foundation for Democracy in February 2005 (Appendix D). The speech recording was about 15 minutes long and was spoken by a native speaker of American English at 130 words per minute (wpm). The speech text had been previously used for simultaneous interpretation practice in an undergraduate course in oral interpreting at a university in Taiwan. The students in the class had not received professional training prior to taking the course and according to the course instructor the content of the speech was at a level of difficulty that the students had found "acceptable". Based on the fact that the bilinguals in the present study also had no training in interpreting, the speech was thus chosen as the stimulus material for simultaneous interpretation.

Finally, a language background questionnaire adapted from questionnaires used by researchers in bilingualism (Appendix E) was administered to each participant. In addition to some biographical questions such as age, country of birth, and length of stay in the US, in the language background questionnaire, participants were asked to list all the languages they knew, context of and age at exposure, and age at mastery. They were also asked to list the language(s) of instruction from their elementary school through college years. The questionnaire also contained items about language(s) they used when speaking with different people such as parents, siblings, co-workers, classmates, etc. Finally, the participants were asked in the questionnaire to self-assess their proficiency in speaking, listening, reading, and writing in their native language (Chinese) and second language (English) on a seven-point scale (where 1= very little knowledge and 7= use it like a native speaker). These self-evaluative responses were adopted as another index of participants' proficiency in L1 and L2. The final item on the questionnaire asked them to write down their TOEFL scores. The purpose of using the language background questionnaire was to better understand how and when the participants acquired their first, second, or other languages and if their language learning experience had any possible effect on their performance on any tasks in the study.

**PROCEDURE AND DATA SCORING**

The majority of the participants were tested individually in a quiet room; two of them were tested in the student center of the participants' school. For the simultaneous interpretation task, since it was impossible to test all participants in a sound-proof interpreting booth, efforts were made to meet with each of them in a quiet room for task administration including voice recording. Each of them first read and signed a consent form (Appendix F) and was encouraged to ask any questions before proceeding to the actual tasks. I also briefly explained to each participant what s/he was expected to do in each task.

**Working Memory Span Tasks**

Digit span in L1 and L2 were given as the first task to all participants. Random single digits of 0-9 that were organized in three series of increasing digit size were pre-recorded in Chinese and English on an audio cassette. Based on Christoffels et al. (2003), the digits were read aloud at a speed of one per second. Participants first listened to three series of four digits pre-recorded in Chinese; they were then asked to recall aloud in order the digits during the pause after each series. The maximum number of digits that they would recall was set at ten and the task continued until they were no longer able to recall one out of the three series. The largest number of digits recalled before an error was made represented a participant's Chinese digit span. Participants repeated the same procedure for the English digit span and their scores were taken in the same manner.

The second working memory measure administered to participants was the reading span task. The reading span task started with two practice trials in Chinese for participants to get a sense of the kind of sentences they would be reading aloud. In both the trial and actual reading span task, sentences were presented one by one in the center on the computer screen. The sentences appeared in increasing set sizes of two, three, four, and five sentences with participants reading three continuous sets of each set size. While reading aloud each sentence shown on the computer screen, they were asked to also try to remember the last word of each sentence. After presentation of each set, they were instructed to recall as many sentence-final words as possible by writing them down on an answer sheet (Appendix G). Each Chinese sentence ended with a different word and participants were told not to begin writing down the last word they read in a sentence set, as immediate recall for the word or sentence last read is usually the strongest. Procedures for the English reading span test were the same as those for the Chinese reading span. The number of Chinese and English sentence-final words they correctly recalled on the answer sheet was calculated, and these two scores represented a participant's Chinese and English reading span.

**Language Proficiency Measures and Simultaneous Interpretation**

To obtain the first index of participants' language proficiency in L1 and L2, they were asked to engage in a speeded translation judgment task on the computer. The task began with several practice trials, during which participants were encouraged to freely ask questions. For both the practice and actual trials, participants first read either an English or Chinese phrase in the center of the computer screen and were instructed to hold the space bar and not release it until they had fully grasped the meaning of the phrase. It was assumed that participants would spend more time to read stimuli presented in the second than in the first language, as past research has shown (Frenck-Mestre, 2002; Hoover & Dwivedi, 1998). Therefore, the time, in milliseconds (ms), that a participant spent on reading the first English or Chinese phrase (the total duration of holding of the space bar while reading the phrase) was taken as a measure of his or her proficiency in that language.

In the simultaneous interpretation task, all participants listened to the aforementioned 15-minute English speech played on an audio cassette player through headsets and were asked to, while they were listening, orally translate the speech from English into Chinese and were instructed to focus on the “meaning” rather than the individual “words” in the speech. Their interpretation of the speech was recorded on a micro-cassette recorder. And based on the SI recordings, two experienced simultaneous interpreters rated participants’ performance on two measures – SI-T and SI-A (Christoffels et al., 2003). SI-T was a measure based on translation of 10 sentences/segments that were roughly equally distributed in the English speech text. Participants were rated on how well these sentences were interpreted into Chinese, on a scale from 0-3. A score of zero meant that the sentence/segment was not translated at all whereas a score of three meant that the meaning of the original sentence/segment was translated in its entirety into Chinese. Half points were used whenever possible. The scores on the ten sentences were then added up; for example, if a participant got a score of three on each of the ten sentences/segments, his or her SI-T score would be 30. SI-A, on the other hand, was based on rating of the complete audio recording of participants’ interpretation of the English speech into Chinese. They were rated on a scale from 0 to 5 on how well the original text was interpreted. For this performance measure, in addition to evaluating how much of the original text participants were able to grasp and interpret into Chinese, other factors such as tone and voice, confidence, and how well they were able to make sense of themselves were also taken into consideration. The SI-T and SI-A scores completed by the two raters were used to establish inter-rater reliability.

Finally, each participant spent 10 minutes to respond to the language background questionnaire, and the data collected from the questionnaire were analyzed using numbers, percentages, or text descriptions.

## DESIGN OF THE STUDY

To examine if participants who differed in training in interpreting also performed differently on the working memory span tasks, a 2x2 analysis of variance (ANOVA) was performed for both the digit span and reading span tasks resulting from the factorial combination of one between-subject factor (Group: bilinguals with no interpreting training vs. first-year interpreting students vs. second-year interpreting students) and one within-subject factors (Language: Chinese vs. English). And the question regarding whether the three groups of participants who differed in interpreting training had indeed performed differently on the two measures of simultaneous interpretation (SI-A and SI-T) was investigated using two one-way ANOVAs, with group as the independent variable in both ANOVAs and the two measures of simultaneous interpretation performance as the two dependent variables.

The relationship between WM span performance and simultaneous interpretation was examined by performing correlation analysis. Finally, whether the L1 and L2 equally- proficient vs. the L1 and L2 not- equally- proficient participants differed in terms of L1 and L2 WM span was analyzed using a 2x2 ANOVA for each of the two WM span tasks. For both ANOVAs, proficiency group (L1 and L2 equally- proficient vs. L1 and L2 not- equally- proficient) was the between-subject factor and language (Chinese vs. English) was the within-subject factor.

# CHAPTER IV

# RESULTS

In this chapter, the results of the study will be presented in the order of the tasks administered and the analyses performed. Descriptive statistics of results relevant to all research questions will be presented and briefly discussed. In addition, hypotheses in the present study will be tested by exploring the results of a series of ANOVAs. Finally, results from the language background questionnaire will be discussed in descriptive text.

## ANALYSIS OF WORKING MEMORY SPAN

As discussed earlier, the 36 participants of this study were Chinese and English bilinguals who either had no previous training in interpreting or were at different levels of training in interpreting. They therefore were categorized into three different groups based on training in interpreting: bilinguals with no interpreting training, first-year student interpreters, and second-year student interpreters. Each of them, as mentioned in the previous chapter, performed two working memory span tasks in Chinese and English, with Chinese being the native language for all individuals. The results of their performance on these tasks are reported below.

### Results of Digit Span

As shown in Table 3, the mean digit span scores represented the average number of digits in L1 and L2 that each group of participants could successfully recall. As mentioned earlier 10 was the highest digit span score in L1 and L2. Across all three groups, as the trend in Table 3 indicates, participants fared better when the digit span was administered in their native language, Chinese, rather than English. Also, the second-year student interpreters appeared to perform better on both language versions of digit span than the first-year student interpreters, who in turn outperformed the bilingual graduate students who had no training whatsoever in interpreting. Whether the digit span scores differed significantly was further examined by performing an analysis of variance as reported in the following section.

Table 3. Mean scores and standard deviations for three groups' digit span

| | | **Group** | | | | | |
|---|---|---|---|---|---|---|---|
| | | **Bilinguals (n=16)** | | **1st year student interpreters (n=11)** | | **2nd year student interpreters (n=9)** | |
| | | Mean | SD | Mean | SD | Mean | SD |
| Digit Span | Chinese | 7.5 | 1.55 | 7.91 | 1.3 | 8.67 | .71 |
| | English | 4.69 | .70 | 4.91 | .94 | 5.78 | .67 |

To examine whether the three groups differed in their performance in the digit span task, the digit span data were submitted to a 3x2 factorial ANOVA with Group (bilinguals vs. $1^{st}$-year student interpreters vs. $2^{nd}$-year student interpreters) as the between-subject factor and Language (Chinese vs. English) as a within-subject factor. An $\alpha$ level of .05 was used for all statistical analyses. For the ANOVAs involving the two WM span tasks (digit span and reading span), an $\alpha$ level of .025 was used. Effect sizes for the mixed-design ANOVAs were reported as partial eta squared ($\eta_p^2$), which "examines the proportion of variance associated with an effect after removing the variability due to the other effects in the design from the total variability" (Jaccard, 1998, p. 39). Power (1-$\beta$), the probability of rejecting a false null hypothesis, was also reported.

The results of the ANOVA (Appendix H) indicated a significant main effect for Group, $F(2,33) = 4.87$, $p<.025$, $\eta_p^2 = .23$, $1-\beta = .77$. Tukey post hoc tests indicated that second-year student interpreters had higher digit span than bilinguals with no training in interpreting, $p< .025$. However, no other significant group differences were found. The main effect of Language was also found to be significant, $F(1,33) = 177.13$, $p<.001$, $\eta_p^2 = .84$, $1-\beta= 1$, suggesting that participants received higher scores on digit span in Chinese (*Mean* = 8.03) than that in English (*Mean* = 5.13). The interaction between Group and Language, however, was not significant.

**Results of Reading Span**

To explore whether the three groups differed in their performance in the reading span task, the reading span data as shown in Table 4 were submitted to a 3x2 factorial

ANOVA with Group (bilinguals vs. 1st-year student interpreters vs. 2nd-year student interpreters) as the between-subject factor and Language (Chinese vs. English) as a within-subject factor.

Table 4. Mean scores and standard deviations for three groups' reading span

| | | **Group** | | | | | |
|---|---|---|---|---|---|---|---|
| | | **Bilinguals (n=16)** | | **1st year student interpreters (n=11)** | | **2nd year student interpreters (n=9)** | |
| | | Mean | SD | Mean | SD | Mean | SD |
| Reading Span | Chinese | 29.19 | 3.12 | 34.73 | 4.08 | 34.11 | 3.86 |
| | English | 25.31 | 4.87 | 28.18 | 6.18 | 31.78 | 5.38 |

The results of the ANOVA (Appendix H) indicated a significant main effect for Group, $F(2,33) = 6.74$, $p<.01$, $\eta_p{}^2 = .29$, $1\text{-}\beta=.89$. Tukey post hoc tests indicated that second-year student interpreters had higher reading span than bilinguals with no training in interpreting, $p< .01$. However, the reading span difference between first-year student interpreters and bilinguals ($p= .03$) and that between the first- and second- year student interpreters was not significant. The main effect of Language was also found to be significant, $F(1,33) = 32.6$, $p<.001$, $\eta_p^2 = .5$, $1\text{-}\beta = 1$, suggesting that participants received higher scores on reading span in Chinese (*Mean* = 32.68) than that in English (*Mean* = 28.42). The Group by Language interaction, however, was not significant.

## ANALYSIS OF SIMULTANEOUS INTERPRETATION

As discussed earlier, scores of two measures of simultaneous interpretation were obtained for each participant: SI-A and SI-T. The total score for SI-A was 5 and that for SI-T was 30. Two experienced simultaneous interpreters rated the performance of each individual and a correlation analysis was performed for the two sets of scores to establish inter-rater reliability. The inter-rater reliability for SI-T and SI-A were both very high (SI-T: $r = .99$, $p< .001$; SI-A: $r = .97$, $p<.001$), indicating that the two raters' scores were highly agreeable.

### ANOVA Results

The two sets of SI-T and SI-A scores were then averaged to obtain a single SI-T and SI-A score that represented each participant's scores on these measures. Mean SI-A and SI-T scores for the three groups of participants are displayed in Table 5. The data from the mean SI-T and SI-A scores were then analyzed in two one-way analysis of variance (ANOVAs) with SI-T and SI-A as the two dependent variables and group (bilinguals vs. first-year student interpreters vs. second-year student interpreters) as the independent variable for both ANOVAs. An $\alpha$ level of .025 was used to accommodate for the correlation between SI-T and SI-A. Effect sizes were reported as $\eta_p^2$, and power was reported as 1-*β*.

For SI-T, the results of the one-way ANOVA (Appendix I) indicated that the three groups differed significantly in their performance, $F(2,33) = 85.46$, $p<.001$, $\eta_p^2 = .84$, 1-$\beta$= 1. Tukey post hoc tests showed that the second-year student interpreters outperformed the first-year student interpreters ($p<.01$), who in turn outperformed the bilinguals ($p<.001$). The results of the one-way ANOVA for SI-A (Appendix I) also indicated that the three groups were significantly different, $F(2,33) = 73.83$, $p<.001$, $\eta_p^2= .82$, 1-$\beta$= 1. Tukey post hoc tests showed that the second-year student interpreters performed better on SI-A than the first-year student interpreters ($p<.001$). The first-year student interpreters, in turn, outperformed the bilinguals ($p<.001$).

Table 5. Mean scores and standard deviations for SI-A and SI-T of the three groups

| | **Groups** | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | **Bilinguals (n=16)** | | **1st-year student interpreters (n =11)** | | **2nd-year student interpreters (n=9)** | | **Total (n=36)** | |
| | Mean | SD | Mean | SD | Mean | SD | Mean | SD |
| SI-A | .91 | .44 | 2.45 | .38 | 3.47 | .78 | 2.02 | 1.20 |
| SI-T | 6.7 | 3.28 | 17.82 | 3.25 | 23.19 | 3.06 | 14.22 | 7.77 |

*Note*. The maximum score for SI-A is 5 and the maximum score for SI-T is 30.

**Correlation Analysis of Working Memory Spans and Simultaneous Interpretation**

To examine the possible relationship between participants' performance on working memory span tasks and simultaneous interpretation, Pearson product-moment correlation coefficients were computed between different language versions of WM span and the two measures of simultaneous interpretation. As shown in Table 6, with the exception of Chinese digit span, both SI-T and SI-A are correlated significantly with all versions of the WM span tasks. The results suggest that participants who scored higher on the Chinese and English reading spans and the English digit span also tended to have better performance in simultaneous interpretation. Among which the correlations between Chinese reading span and the two measures of simultaneous interpretation were found to be the highest.

Table 6. Correlation between the performance on WM span tasks and two measures of performance on the simultaneous interpretation task, SI-T and SI-A

| Task | SI-T | SI-A |
|---|---|---|
| Chinese Reading Span | .59** | .52** |
| English Reading Span | .50** | .43** |
| Chinese Digit Span | .31 | .30 |
| English Digit Span | .46** | .49** |

*Note*. ** $p < .01$.

## ANALYSIS OF LANGUAGE PROFICIENCY AND DIFFERENCE IN L1 AND L2 WORKING MEMORY

Reading time data in the translation judgment task and self-evaluation of language skills in L1 and L2, as mentioned in the previous chapter, were two indices used to evaluate the L1 and L2 proficiency of all participants. Reading times were first computed for each participant and the data were then ranked from the participant who showed the closest reading time difference between L1 and L2 to the ones showing the largest difference. Closer reading times between L1 and L2 is an indication that the participant was more equally proficient in the two languages.

As participants also self-evaluated their reading, writing, listening, and speaking skills in the two languages on a seven-point scale, the points were added up for each language. These data were also ranked from participant who had the lowest difference between self-evaluation of L1 and L2 to ones that had the largest difference. Correlation coefficient was computed for the two indices.

### Reading Time Data

As mentioned earlier, in the translation judgment task each participant first read a Chinese or an English phrase while holding the space bar on the computer, when they released the space bar a second phrase appeared which was either a literal, figurative, or non-translation of the first phrase. For both the Chinese and English as first phrase conditions, two reading times were obtained for each participant: one for when the second phrase was a figurative translation and the other for when the literal translation was the second phrase. As a result, there were two reading time data for each participant's L1 and L2. The two reading times in L1 and L2 were then averaged so that participants' language proficiency was computed using only one reading time for each language. For instance, if a participant's average reading time was 2000 ms for English phrases which were followed by Chinese figurative translations and 1800ms for English phrases which were followed by Chinese literal translations, his or her English reading time would be 1900 ms. The English reading times for all participants were found to be longer than Chinese reading times, suggesting that all participants took longer times to read phrases in their L2.

**Data from Self-Evaluation of Language Skills in L1 and L2**

Participants rated their Chinese and English skills each on a scale of one to seven (1 = very little knowledge, 7 = use it like a native speaker). Since they were asked to self asses their language proficiency in listening, speaking, reading, and writing in the two languages, four scores were obtained for L1 and L2 and then scores for each language were added up. Hence, a participant who gave a score of seven for each language skills in L1 and L2 would have a total score of 28 for each language. All participants rated their Chinese language skills as being better than English skills.

**Categorization of Participants as L1 and L2 Equally-Proficient and Not-Equally-Proficient**

The distance between each participant's Chinese and English reading times (L2 –

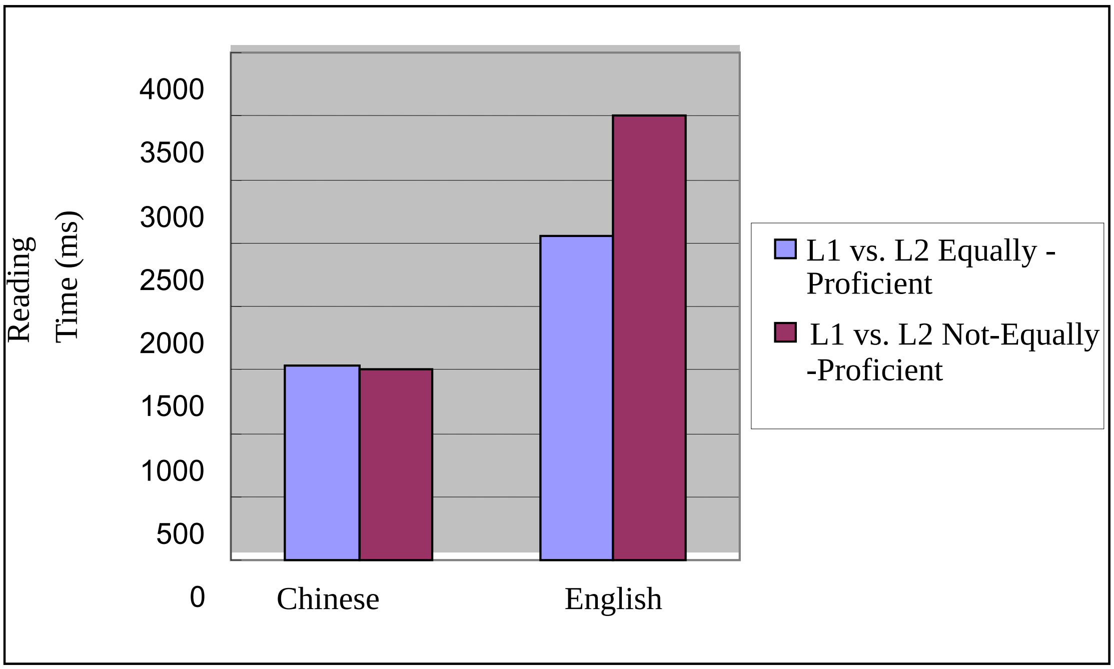
L1 reading time) as well as the difference between their Chinese and English self-evaluation scores (L1 – L2 self assessment scores) were then computed in order to categorize them into two subgroups - L1 and L2 equally- proficient vs. L1 and L2 not-equally- proficient. Spearman rho correlation coefficient was computed between these two scores. Since many participants' L1 and L2 self-evaluation scores differences were the same, converting the original raw scores into rankings would result in a more accurate indication of the association between the two indices.

Correlation between the two indices was found to be significant, $\rho = .39$, $p < .05$, suggesting that shorter distance between L1 and L2 reading times is associated with smaller difference between participants' L1 and L2 self assessment scores. In categorizing participants into either of the two groups, I compared the first half (18) of those who had the lowest differences on the two indices and found that 12 participants belonged to the first half on both indices. In other words, compared with the other 24 participants these 12 participants rated themselves as having more similar L1 and L2 language proficiency and showed closer reading times between L1 and L2. They were then classified as the L1 and L2 equally- proficient group, and the remaining 24 participants were classified as the L1 and L2 not- equally- proficient group.

As shown in Figure 2, participants in the L1 and L2 not- equally- proficient group spent longer times (ms) reading phrases in English (*Mean* = 3501.43, *SD* = 852.01) than the L1 and L2 equally- proficient group (*Mean* = 2548.86, *SD* = 427.33). Results of a t-test (Appendix J) showed that the difference between the two groups was significant, $t(33.98) = -4.47$, $p < .001$. On the other hand, the difference between the reading times in

Chinese for the L1 and L2 equally proficient group (*Mean* = 1537.15, *SD* = 459.06) and the L1 and L2 not equally proficient group (*Mean* = 1498.55, *SD* = 368.65) was not significant, $t(34) = .27$, $p = .79$ (Appendix J).

Figure 2. Chinese and English phrase reading time for the two proficiency groups

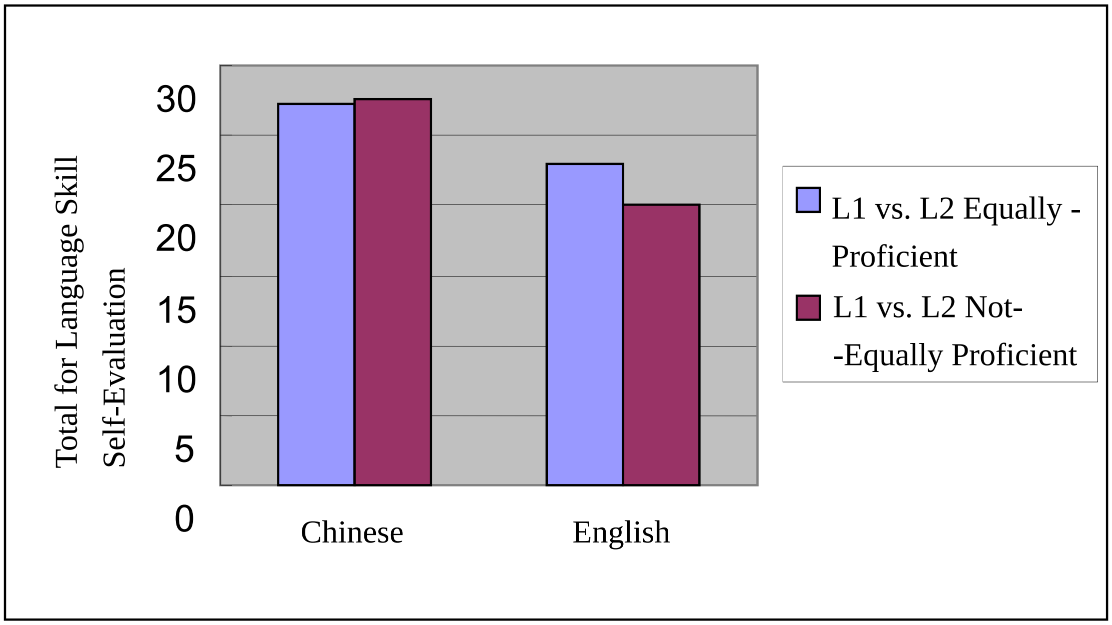



The two proficiency groups' total score on self-evaluation of Chinese and English skills are shown in Figure 3. In terms of English, the L1 and L2 equally- proficient group, on average, had a higher total score (*Mean* = 22.96, *SD* = 1.98) than the L1 and L2 not-equally- proficient group (*Mean* = 20.08, *SD* = 2.34). Further t-test (Appendix J) showed that the difference was statistically significant, $t(34) = 3.65$, $p<.01$. The L1 and L2 equally- proficient group's total score for self-evaluation of Chinese (*Mean* = 27.33, *SD* = 1.23) was very similar to the other group's total score (*Mean* = 27.58, *SD* = 1.23). A t-test (Appendix J) showed that this difference was not statistically significant, $t(34) = -.57$, $p = .57$.

Results from the mean comparisons based on the two language proficiency indices indicated that the two groups were equally proficient in L1, their native language, but were different in their L2 proficiency. In other words, it was proficiency in L2 that differentiated the two groups. An additional t-test (Appendix K) was performed to examine if the two proficiency groups also differed in their TOEFL, a test that measures language proficiency in English. Results showed that the TOEFL score difference between the L1 and L2 equally- proficient group (*Mean* = 640.91, *SD* = 14.46) and the L1 and L2 not- equally- proficient group (*Mean* = 602.14, *SD* = 52.21) was significant, $t(25.21) = 3.18$, $p<.01$, showing that the L1 and L2 equally- proficient group outperformed the not- equally- proficient group on an English proficiency standardized test[5].

[5] The t-test performed for the two proficiency groups' TOEFL scores was based on scores from 32 participants who had taken the test and reported their scores.

Figure 3. Total score of Chinese and English skills self-evaluation for the two proficiency groups




**L1 vs. L2 Digit Span for the Two Proficiency Groups**

To explore whether participants who were classified as equally- proficient in L1 and L2 differ in terms of L1 and L2 digit span and if those who were classified as not-equally- proficient in L1 and L2 exhibit more digit span in L1 than L2, a 2x2 analysis of variance (ANOVA) was performed resulting from the factorial design of one between-subject factor (Proficiency Group: equally proficient vs. not equally proficient) and Language (Chinese vs. English) as a within subject factor. The means and standard deviations for the two groups' digit span in Chinese and English are displayed in Table 7.

Table 7. Means and standard deviations for two proficiency groups' Chinese and English digit span

| | | **Proficiency Group** | | | |
|---|---|---|---|---|---|
| | | **L1 and L2 Equally-Proficient (n=12)** | | **L1 and L2 Not- Equally-Proficient (n=24)** | |
| | | Mean | SD | Mean | SD |
| Digit Span | Chinese | 8.58 | 1.0 | 7.58 | 1.41 |
| | English | 5.33 | .89 | 4.88 | .85 |

Results of the ANOVA (Appendix L) indicated a significant main effect for Language, $F(1,34) = 188.57$, $p<.001$, $\eta_p^2 = .85$, $1\text{-}\beta= 1$, suggesting that participants had higher digit span in Chinese (*Mean* = 8.08) than in English (*Mean* = 5.1). The main effect of Proficiency Group was not found to be significant, $F(1,34) = 5.13$, $p=.03$, $\eta_p^2 = .13$, $1\text{-}\beta=.60$. The interaction between Proficiency Group and Language was also not significant.

**L1 vs. L2 Reading Span for the Two Proficiency Groups**

To explore whether participants who were classified as equally- proficient in L1 and L2 differ in terms of L1 and L2 reading span and if those who were classified as not-equally- proficient in L1 and L2 exhibit more reading span in L1 than L2, a 2x2 analysis of variance (ANOVA) was performed resulting from the factorial design of one between-subject factor (Proficiency Group: L1 and L2 equally- proficient vs. L1 and L2 not- equally- proficient) and one within-subject factor (Language: Chinese vs. English). The means and standard deviations for the two groups' reading span in Chinese and English are displayed in Table 8.

Table 8. Means and standard deviations for two proficiency groups' Chinese and English reading span

| | | **Proficiency Group** | | | |
|---|---|---|---|---|---|
| | | **L1 and L2 Equally-Proficient (n=12)** | | **L1 and L2 Not- Equally-Proficient (n=24)** | |
| | | Mean | SD | Mean | SD |
| Reading Span | Chinese | 34.17 | 3.64 | 31.08 | 4.46 |
| | English | 30.42 | 3.73 | 26.5 | 6.38 |

Results of the ANOVA (Appendix L) indicated a significant main effect for Language, $F(1,34) = 26.6$, $p<.001$, $\eta_p^2 = .44$, $1-\beta=.99$, suggesting that participants had higher reading span in Chinese (*Mean* = 32.63) than in English (*Mean* = 28.46). The main effect of Proficiency Group was not found to be significant, $F(1,34) = 4.98$, $p =.03$, $\eta_p^2 = .13$, $1-\beta= .58$. The interaction between Proficiency Group and Language was also not significant.

**Additional Analysis on the Two Proficiency's Group's Simultaneous Interpretation Performance**

Though not directly related to the present study's research question, I was interested in exploring if the two proficiency groups differed in the two measures of simultaneous interpretation performance – SI-T and SI-A. Therefore, two one-way ANOVAs were performed using SI-T and SI-A as the two dependent variables and proficiency group (L1 and L2 equally- proficient vs. L1 and L2 not- equally- proficient) as the independent variable for both ANOVAs. An $\alpha$ level of .025 was used to accommodate for the correlation between SI-T and SI-A. Effect sizes were reported as $\eta_p^2$, and power was reported as 1-$\beta$. The means and standard deviations of the two proficiency groups' SI-T and SI-A performance are shown in Table 9.

Table 9. Means and standard deviations for two proficiency groups' SI-T and SI-A

| | **Proficiency Group** | | | |
|---|---|---|---|---|
| | **L1 and L2 Equally-Proficient (n=12)** | | **L1 and L2 Not-Equally-Proficient (n=24)** | |
| | Mean | SD | Mean | SD |
| SI-T | 19.04 | 5.51 | 11.81 | 7.69 |
| SI-A | 2.69 | .95 | 1.69 | 1.18 |

Results of the one-way ANOVA for SI-T (Appendix M) indicated that the two proficiency groups were significantly different in their SI-T performance, $F(1,34) = 8.39$, $p<.01$, $\eta_p^2 = .20$, $1\text{-}\beta = .65$, suggesting that the L1 and L2 equally- proficient group scored higher on SI-T than the not- equally- proficient group. For SI-A, the analysis of the one-way ANOVA (Appendix M) showed that the two groups were also significantly different, $F(1,34) = 6.47$, $p<.025$, $\eta_p^2 = .16$, $1\text{-}\beta = .50$, an indication that the L1 and L2 equally- proficient group outperformed the not- equally- proficient group in SI-A.

## ANALYSIS OF LANGUAGE BACKGROUND QUESTIONNAIRE

### Participants' Report of Language Use

In the language background questionnaire, in addition to biographical information participants were also asked age at and context of exposure as well as age of mastery of their first, second, or third languages. Since all participants reported Chinese as their first language, they all said that they were exposed to Chinese at home since childhood. As for English, their second language, all said they started to learn the language at school at around 9 to 12. As for other third or fourth languages, they also said the languages were learned at school, usually after 12. For all their languages, participants reported age of mastery to be after 12. It should be noted that the language background questionnaire only provided age selection in ranges: 0-4 yrs, 5-8 yrs, 9-12 yrs, or >12, therefore when participants reported >12 it could mean that they mastered the language after 18, 20, or even older.

Further, in the language background questionnaire participants were asked what other languages they knew in addition to Chinese and English. Eleven mentioned Japanese, five said German, five mentioned French, three said Taiwanese, and two knew Spanish. Korean, Russian, and Cantonese were each mentioned once. Four participants said they knew two of the above languages in addition to Chinese and English, and one listed three languages. In addition, participants reported what languages were used for instruction from elementary school to college and the language(s) they spoke with different addresses. Unsurprisingly, almost all participants stated that Chinese was used as the language of instruction from their elementary to college years given the fact that most of them had received pre-graduate school education in their home countries. However, both English and Chinese were used as languages of instruction in college for several participants.

As for the languages they spoke with different addresses including parents, siblings, friends, classmates, partners, etc., Chinese still appeared to be the dominant language, although English was also used when speaking with classmates, friends, or co-workers.

Given that the majority of participants were attending graduate schools in an English-speaking environment, it was quite natural that they would use English to converse with their classmates or friends.

# CHAPTER V

# CONCLUSION

In this chapter, I will present the findings based on the results in the previous chapter and discuss their implications. The limitations of the study will be addressed and the study's contribution to literature as well as to the training of simultaneous interpreters will be discussed. The final section will be devoted to the study's implications for future research. Before proceeding to discussion of the findings, the present study's three major hypotheses are restated in the following:

(a) Participants who are at more advanced levels of training in interpreting will show better performance in simultaneous interpretation and will also have higher scores on the reading span and digit span tasks.

(b) For participants who are classified as equally- proficient in L1 and L2, no significant difference will be observed in working memory span tasks administered in L1 (Chinese) and L2 (English).

(c) Participants who are classified as not- equally- proficient in L1 and L2 will show higher scores in L1 than in L2 working memory span.

## DISCUSSION OF FINDINGS

### The Role of Training in Interpreting in Simultaneous Interpretation Performance

The results of the study support the hypothesis that training in interpreting contributes to better performance in simultaneous interpretation as attested by the second- and first - year student interpreters' better performance than the bilinguals on both SI-T and SI-A, the two measures of simultaneous interpretation. The second-year student interpreters, in turn, also scored higher than first-year student interpreters on both SI-T and SI-A. The student interpreters' overall better performance was actually not unexpected, as one would expect professional training in simultaneous interpretation to result in improved performance in the task per se. The student interpreters of the present study went through the requirements in a graduate school of translation and interpretation so that they could achieve the goal of eventually becoming professional interpreters who could distinguish themselves from other bilinguals who may have excellent command of two languages but lack training and experience in interpreting.

Not only did the three groups differ in their simultaneous interpretation performance, there was in fact a wide performance gap between the student interpreters and bilinguals with no training in interpreting: none of the bilinguals scored over 1.75 whereas 4.25 was the highest score for the student interpreters on SI-A. Further, while the bilinguals only averaged 6.7 ($SD$ = 3.28) on the SI-T, the student interpreters averaged 20.24 ($SD$ = 4.13). Due to their training in interpreting, both groups of student interpreters were more capable of grasping the meaning of sentences or segments in the English speech text and render them into Chinese while at the same time they were also more confident in their overall delivery.

A comparison of the recording of the simultaneous interpretation output showed that there was a clear difference in the three groups' performance. This difference is even more pronounced when comparing the performance of student interpreters with that of bilinguals with no training in interpreting. The output of the bilinguals was usually marked by long moments of silence; and when they did attempt to interpret the speech, they had a tendency to be preoccupied with providing translations for individual words or phrases rather than transposing meaning units of the input speech into complete sentences in the target language. On the other hand, despite having had no prior training in simultaneous interpretation, two of the bilinguals received SI-T scores that were comparable to two of the first-year student interpreters. This suggests that simultaneous interpretation may indeed be attainable without formal training.

## The Role of Training in Interpreting in Working Memory Span Performance

Comparison among the first-year student interpreters, second-year student interpreters, and bilinguals with no training in interpreting in their performance of working memory span tasks showed that the second-year student interpreters outperformed bilinguals on all language versions of the working memory span. However, second-year student interpreters did not show an advantage over the first-year student interpreters on any of the working memory span tasks, while the first-year student interpreters also did not outperform the bilinguals on these tasks.

Therefore, a comparison between second-year student interpreters and bilinguals showed that two years of training in interpreting did contribute to better performance in the working memory span tasks. The findings also suggested that a year’s training in interpreting for the first-year student interpreters did not make a difference in working memory when compared with the bilinguals. In addition, no difference in working memory was observed between student interpreters at different levels of training, suggesting that an additional year of training in interpreting did not improve the second-year student interpreters' working memory any further (assuming the second-year student interpreters' memory spans a year ago were similar to those of the first-year student interpreters).

## The Relationship between Simultaneous Interpretation and Working Memory Span Performance

The two measures of simultaneous interpretation were found to be correlated with all versions of working memory span, except the Chinese digit span task. These results suggest that a larger working memory is associated with better performance in simultaneous interpretation. The fact that performance of simultaneous interpretation from English into Chinese is correlated with both Chinese and English reading spans indicates that the two tasks may impose similar cognitive demands on participants. As discussed earlier, the reading span task has been widely used to measure the ability of an individual to store and process information at the same time. Simultaneous interpretation, meanwhile, is a task that also involves storing and processing of incoming speech simultaneously. Further, the interpretation of an English text into Chinese involves the activation of two language systems at the same time, though the activation of the target language is presumably stronger (Paradis, 1994). Performance on simultaneous interpretation, as such, is inevitably relative to an individual's command of the two languages involved in the task. Given the similar demands of reading span and simultaneous interpretation and the fact that the reading span was administered also in Chinese and English, their association with a simultaneous interpretation task involving these two languages is not unfounded.

On the other hand, English digit span, not Chinese digit span, was found to correlate with simultaneous interpretation performance in this study, an indication that recall of numerals in L2 is associated with simultaneous interpretation from L2 into L1. Although digit span, like reading span, is a short-term memory task, digit span probably involves more passive storage instead of active processing. That is, the participants didn't necessarily have to "comprehend" the digits as they did for the reading span task. Therefore, digit span's association with simultaneous interpretation may be focused more on the storage or recall aspect rather than the processing or production aspect. Moreover, the digit span task only required participants to engage in passive listening of the digits without concurrently repeating them, which is quite different from reading aloud sentences and recalling final words in the reading span task or speaking while listening to spoken message in simultaneous interpretation. In light of the different demands between the digit span task and simultaneous interpretation, the association between the two tasks may not be as strong as that between reading span and simultaneous interpretation. A probable explanation for why English digit span was found to be correlated with both SI-T and SI-A is that participants had to recall a lot of information involving numbers in the English speech. Out of the ten sentences or segments on which the scores for SI-T were based, four involved recall and processing of numbers in English.

It is interesting to note that correlations were generally lower for SI-A, a measure that was largely based on aspects that were more subjective (e.g. tone, voice, confidence, etc.). For SI-T, on the other hand, the two raters looked at how well individual sentences or segments were translated into Chinese and had the original speech transcript as some sort of “bench mark”. This is perhaps why the inter-rater reliability for SI-A was also lower than that for SI-T.

**The Role of Language Proficiency in Working Memory Span Tasks**

Regardless of groupings according to language proficiency in L1 and L2, all participants showed higher working memory in L1 than in L2, suggesting that all participants performed better in working memory span tasks administered in their native language. As a result, the hypothesis that the L1 and L2 not-equally-proficient group will show a difference in working memory span administered in their L1 and L2 is supported. On the other hand, the hypothesis that no significant difference will be observed in L1 and L2 working memory span tasks for the L1 and L2 equally- proficient group is not supported by the results of the present study.

In other words, classifying participants as L1 and L2 equally-proficient vs. L1 and L2 not-equally-proficient did not yield parallel performance in L1 and L2 working memory. Perhaps none of the participants in the present study should be classified as equally- proficient in L1 and L2 since neither of the two indices of language proficiency point to any of them being truly equivalent in the two languages. Since the two groups were not significantly different in their Chinese language proficiency and differed only in English proficiency, at the most, it could only be said that one group is relatively more similar in proficiency across their two languages.

It is interesting to note, however, that despite the fact that the native language advantage was shown in working memory for both proficiency groups, participants who were categorized as equally proficient in two languages had better performance on the two measures of simultaneous interpretation. Hence, language proficiency in L1 and L2 seemed to mediate performance in simultaneous interpretation. Given that simultaneous interpretation involves the activation of two languages, the results would seem unsurprising.

## LIMITATIONS OF THE STUDY

### Limitations Related to Participant Recruitment

Due to the limited number of participants in the present study, claims cannot be made regarding the generalizations of the results to different Chinese-English student interpreter or bilingual populations. The busy schedules on the part of the student interpreters who were approaching the end of their first or second year terms prevented a number of them from signing up to take part in the various tasks that required a total of about one and a half hours. As for the regular bilinguals, since during the time of data collection I moved to another city, recruiting Chinese and English bilinguals from a school and city with which I was not familiar turned out to be quite challenging. In addition, during the time of the study, there was only one institution in the United States that offered a formal two-year graduate program in interpreter training, the results pertaining to the role of interpreter training in working memory enhancement would probably not be representative of students who were undergoing interpreter training in other language combinations, or for that matter, in other parts of the world such as Europe, Australia, or other Asian countries.

**Issues of Ecological Validity**

Although the majority of the student interpreters were able to meet with me in a quiet classroom without any noise disturbance, a couple of the bilinguals met with me at their school's student center, which was not a completely noise-free environment. As a result, they may have been somewhat distracted and hence their performance on the tasks could be affected. In real-life situations, simultaneous interpreters usually work in sound-proof booths. It has to be noted, however, that during simultaneous interpretation all participants listened to the English speech through a headset so all were able to clearly listen to the speech despite any noise distractions.

In terms of task administration, due to consideration that starting an unfamiliar task in participants' L2 might "intimidate" them, all participants completed the tasks in the same order, i.e., they first completed the digit and reading spans in Chinese and then English. It is unclear whether this manipulation of language order had an effect on how participants performed in ensuing tasks. Based on results showing that English digit and reading spans were lower than their Chinese counterparts for all participants, it raises the interesting question of whether administering working memory spans in L1 first contributed in anyway to the lower L2 working memory spans.

As for the materials used in this study, stimulus sentences for the Chinese and English reading spans were selected from a previous research study as well as from published materials written by native English and Chinese speakers, and I personally judged whether the sentences fit the criteria for inclusion in the reading span task. As an experienced Chinese–English translator and interpreter, despite having good command of both languages, I would have certainly benefited from asking a native English speaker and another Chinese speaker to review the sentences in order to increase the reliability of sentences used in the reading spans, but this was not possible owing to the fact that the development of stimuli was conducted under a rather severe time constraint. The same thing can be said of the phrases used in the translation judgment task. The study would have greatly benefited by including a second or third person's opinion regarding the selection of Chinese and English phrases rather than relying solely on published texts.

The English speech was read at a rather high speed and lacked the natural pauses, redundancy, and other characteristics commonly seen in an impromptu speech (Dejean le Feal, 1982) or a speech delivered without reading a text. For the student interpreters in this study who interpreted read speeches quite frequently, as in class they often practiced interpreting speeches that their instructors read from transcripts, listening to and interpreting such a speech did not seem as unnatural as it did to the bilinguals who never had any exposure to training in simultaneous interpreting. Many of the bilinguals commented after the task that they found the speech to be very dense and that it didn't sound like a natural speech. Given that in real conference situations, even simultaneous interpreters find it more difficult to interpret for a speaker who reads his or her speech

(Dejean le Feal, 1982), it is probable that not using an original speech delivered at a conference or meeting affected the performance of bilinguals who otherwise would have performed better. Also, although each participant was told that the first several minutes of their interpretation of the speech were considered a “warm-up” and would not be evaluated, a practice or coaching session, especially for the sake of the bilinguals, would likely familiarize them better with the task of simultaneous interpretation.

Moreover, the simultaneous interpretation task only asked participants to interpret from L2 into L1. Research has shown that interpreting from L1 into L2 requires more effort and often leads to more errors (Seleskovitch, 1999) and it has been a standard practice in the profession for simultaneous interpreters to work only into their native language (Schweda-Nicholson, 1992). These reasons explain why simultaneous interpreters find it easier to work into their native language. However, interpreters also work into L2 when such job opportunities arise, and interpreting from L1 into L2 does afford the advantage of better comprehension of source speech. In fact, Barik (1975) compared the simultaneous interpreting performance of professional conference interpreters, student interpreters, and fluent bilinguals without interpreting experience and found that the fluent bilinguals performed better when the source language was their native language and the target language was their second language. Similar results were also obtained in Tommola et al.’s (2000/2001) study in which the participants consisted of professional interpreters. Since the present study only tested simultaneous interpretation in one direction, claims about the association between working memory and simultaneous interpretation or the role of training in simultaneous interpretation can only be made for simultaneous interpretation from L2 into L1.

## IMPLICATIONS FOR THE LITERATURE

The present study examined the role of training in interpreting in simultaneous interpretation performance by employing an actual simultaneous interpretation task, which as was done in very few studies. Further, two groups of bilinguals were compared: one without training in interpreting and the other with one or two years of training in interpreting. In the following I will discuss the results of the present study in relation to those of previous studies. I will also highlight the major contribution of this study to the literature.

### Working Memory and Simultaneous Interpretation

In the present study, all language versions of the working memory tasks were found to correlate with simultaneous interpretation performance except L1 digit span. In Christoffels et al.'s (2003) study, which also included a simultaneous interpretation task into L1, only reading span in L2 was found to be directly related to performance in simultaneous interpreting. However, the participants in Christoffels and colleagues' study consisted of only Dutch and English bilinguals with no training in interpreting and excluded digit span in L2, whereas the present study included both Chinese and English bilinguals with and without training in interpreting and had digit span in both L1 and L2. Moreover, compared to the present study's 15-minute long English speech, the English speech that participants in Christoffels et al.'s study was asked to interpret was only about four minutes in length, which probably was too short to accurately gauge the bilinguals' ability to perform the task of simultaneous interpretation. In light of the fact that this study included two additional groups of participants with actual experience in interpreting and used a longer speech for the SI task, the finding that both L1 and L2 reading span and L2 digit span are related to performance in simultaneous interpretation is possibly more tenable.

## Training in Interpreting and Working Memory

The findings of this study indicate that students at advanced levels (second-year) of training in interpreting exhibited higher working memory than bilinguals without training in interpreting, although the advanced level students did not perform better than students at beginning levels (first-year) on the working memory span tasks. No performance difference was observed between first-year student interpreters and bilinguals either. While Padilla et al.'s (1995) study showed significant difference in working memory between the professional interpreters and students of an interpreting program from two different levels of training, they could not investigate whether there was also an effect of training in interpreting on working memory for students in the second and third year of the interpreting program since the second-year students had not been exposed to training in simultaneous interpretation.

## Language Proficiency, Working Memory, and Simultaneous Interpretation

Contrary to Service et al.'s (2002) study that suggested higher L2 working memory for more advanced speakers of L2, the present study did not confirm an L2 advantage in working memory span performance for more proficient L2 speakers (L1 and L2 equally-proficient group). Nevertheless, it is worth noting that the present study showed that a better command of L2 or high proficiency in both L1 and L2 contributed to better simultaneous interpretation performance. As such, this study suggested that proficiency in language may be reflected in how individuals fare on a simultaneous interpretation task. Though participants who had better L1 and L2 proficiency did not seem to also have better or equal L1 and L2 working memory span performance, this study's findings provide support to claims about the important role that language proficiency plays in simultaneous interpretation.

## IMPLICATIONS FOR SELECTION AND TRAINING OF SIMULTANEOUS INTERPRETERS

Simultaneous interpretation is said to be one of the most complex language processing tasks (Frauenfelder & Schriefers, 1997) and can be achieved only by bilinguals or multilinguals who have superior memory and language skills. One of the most striking difficulties simultaneous interpreters have to cope with is the simultaneity of comprehension and production: the input message has to be comprehended in the source language, temporarily stored while dealing with an incoming message, and eventually rendered into the target language. It can be easily understood, then, why memory skills are crucial in interpreting. Working memory, in the present study, was also found to relate to performance in simultaneous interpretation, which has implications for the training of simultaneous interpreting.

In terms of selecting potential candidates to be trained in simultaneous interpretation, the results of the present study suggest that working memory measures such as reading span, digit span, and/or other variations of working memory span tests can be administered to students or individuals who are interested in becoming trainees of interpreting programs as pre-screening measures. Selecting those who have better performance on these working memory span measures will probably also lead to better success once the students enter the training program.

The finding of this study that the second-year student interpreters outperformed regular bilinguals in working memory span measures suggest that training in interpreting may have contributed to enhancing working memory. Due to the lack of difference in working memory between the first – and second –year student interpreters, the same claim could not be made for those at different levels of training in interpreting. Their similar working memory performance also lends support to the possibility that these student interpreters had initially entered the program with comparable working memory capacities. If this is the case, then interpreting training by itself, according to the study's results, did not increase their memory spans any further. However, since the two groups of student-interpreters were tested near the end of the academic year, it is unclear if the first-year student interpreters had lower memory spans when they first entered the program.

Despite their similar working memory span performance, the second-year student interpreters performed better on simultaneous interpretation than the first-year student interpreters. Further, the first-year student interpreters also had better simultaneous interpretation performance than the bilinguals, though the two groups' working memory was not different. The implications of these findings for the training of simultaneous interpreters is that possessing a certain level of skill in working memory might make a person more "fit" to be trained in the task, but achieving higher levels of success probably requires higher levels of skill. In other words, working memory can be regarded as a general cognitive ability that anyone can have. As suggested by Liu et al. (2004), expertise in interpreting can probably be better achieved through extensive experience in the task rather than through training in a general cognitive skill such as working memory. Nonetheless, possessing certain types of language or cognitive skills like memory skills may still predict performance in interpreting. Gerver, Longley, Long, and Lambert (1984), for instance, used a battery of ability tests to predict final grades of trainees in an intensive interpreting program and found that recall tests and cloze tests predicted performance in consecutive and simultaneous interpretation respectively. Hence, both innate skills and training and extensive experience in interpreting appear to be important for optimal performance in simultaneous interpreting.

Another finding of this study that has important implications for training in interpreting is that having a more equal command of L1 and L2 language proficiency may lead to better performance in simultaneous interpretation. As expected, all but one of the participants classified as equally- proficient in L1 and L2 were from the student interpreter group who supposedly had better proficiency in L2. Simultaneous interpretation training, then, is inextricably tied to continual training and improvement of language skills. In fact, much of the initial training in interpreting involves basic language skills such as verbalizing synonyms for terms in L1 and L2 (Bajo et al, 2000), as rapid access to lexical items is required for interpreters who during the course of interpreting must come up with equivalent words or phrases in the target language.

Two of the participants in this study who reported having lived in the United States for over ten years were also in the L1 and L2 equally-proficient group, an indication that immersion in the L2 cultural environment for an extended period of time can greatly contribute to L2 language proficiency improvement. In fact, some translation and interpretation graduate schools, for instance, the Fun-Jen Graduate School of Translation and Interpretation in Taiwan, do require that students who are studying in the interpreting training program spend at least a year in an L2 speaking environment. On the other hand, the difference in the two proficiency group's TOEFL scores also showed that a higher command of L2 is critical for optimal performance in simultaneous interpretation.

## IMPLICATIONS FOR FUTURE RESEARCH

The present study did not provide an affirmative answer as to whether training in interpreting results in higher efficiency in working memory. The Chinese-English bilinguals who had not received training in interpreting exhibited lower reading and digit spans than the second-year student interpreters, but a significant difference in working memory between student interpreters at different levels of training was not obtained. Previous studies comparing novice and professional interpreters have suggested that working memory can best be understood as a general aptitude and that better performance in interpreting has more to do with domain knowledge and skills rather than working memory (Liu et al, 2004; Köpke & Nespoulous, 2006). Nevertheless, the results of this study and other prior ones as reviewed in earlier chapters did indicate some association between working memory and simultaneous interpretation performance.

In future research, it would therefore be important to confirm if training in interpreting, a task that taps a person's storage capacity, does indeed have an effect on increasing the cognitive skill of working memory. It would be interesting to compare the working memory in a given group of student interpreters followed from the beginning up to the end of a formal training program. In other words, future studies should employ a longitudinal design and follow the same cohort of trainees of interpreting for one or two years. If this were done, questions regarding whether working memory can be further enhanced by training in interpreting would be more easily sorted out.

Proficiency in L1 and L2 was identified as an important determinant of simultaneous interpretation performance. Not only was working memory span in L1 higher than that in L2 across all participant groups, the L1 and L2 equally-proficient group who had higher proficiency in L2 showed significantly better performance on the simultaneous interpretation task than the L1 and L2 not-equally-proficient group. On the other hand, word knowledge in L1 has been found to be most important for the task of simultaneous interpreting (Padilla et al., 2005). What would be worth investigating in future research is whether skills in L1, L2, or both have a decisive impact on success in simultaneous interpretation by using a variety of tests to measure L1 and L2 language proficiency. The present study used self-evaluative and reading time measures to determine participants' proficiency in L1 and L2. Future studies can use more comprehensive tests that behaviorally measure bilinguals' reading, writing, listening, and speaking skills to identify the specific language skills that are most critical to success in simultaneous interpreting. Further, this study only tested simultaneous interpretation into L1. As interpreting into L1 vs. L2 is not the same, the language skill levels involved may also be different. Future studies can examine if superior performance in simultaneous interpretation into L1 vs. L2 entails different levels of language skill.

## SUGGESTIONS FOR FUTURE RESEARCH

Future studies can consider comparing different groups of bilinguals or bilinguals from different language combinations. One point in this regard is that any study that intends to draw a conclusion regarding the relation of particular skills to simultaneous interpretation is that an actual simultaneous interpretation task must be included. Although several previous studies made efforts to include different bilingual groups, many failed to ask the participants to interpret an actual speech. Perhaps the main consideration was that most bilinguals are not familiar with the task of simultaneous interpretation. This is why researchers interested in conducting related research need to provide some sort of coaching or training prior to administering the task to bilinguals with no training in interpreting. The present study as well as that by Christoffels et al. (2003) showed that bilinguals are capable of producing at least some output, so appropriate practice and training are key to producing better research results.

As for comparing bilinguals who speak different languages, future studies can, for example, include Spanish-English interpreters and/or bilinguals in the same study with Chinese-English bilinguals. To date, very few studies have included bilinguals who spoke different language combinations that are very different in sentence structure in the same study. By comparing bilinguals whose L1 and L2 are more similar in sentence structure with those whose L1 and L2 are more distant in sentence structure, more knowledge may be gained regarding whether difference in language structure impose varying demands on working memory in L1 and L2.

Due to the limited scope of this study, the output of simultaneous interpretation from each participant was not analyzed and compared in a very detailed fashion. How participants rendered a particular word or sentence into the target language was not examined but offers potentially rich data for future investigations in interpreting discourse. From my personal observation of the interpretation output, something very interesting that I have discovered is that two participants may have equivalent scores on either the SI-A or SI-T measure but their output would be completely different on the word-to-word and/or sentence-to-sentence level. Some participants' interpretation would follow the source text more closely, while others were not afraid to lag farther behind and provide a translation that diverged more from the source text's syntactic structure. More effort should be put into studying the output of simultaneous interpretation to shed light on, for instance, the characteristics of interpretation discourse of interpreters at different levels of expertise.

**CONCLUSION**

The present study explored the roles of working memory, L1 and L2 language proficiency, and training in interpreting in performance in simultaneous interpretation and the possible relation among these variables. It was assumed that working memory would be a major determinant of performance in simultaneous interpretation and that training in interpreting would further enhance working memory. Although the present study failed to provide strong support for the hypothesis that training in interpreting leads to higher working memory, results of the study did show a positive link between working memory and performance in simultaneous interpretation. The unresolved question of this study seems to be whether the two groups of student interpreters, who performed better on the simultaneous interpretation task, entered the interpreter training program equipped with similar working memory.

Another variable that comes into play in simultaneous interpretation performance, based on the results of this study, is language proficiency in L1 and L2. Those who exhibited high proficiency both in L1 and L2 appeared to also have better performance in simultaneous interpretation, though their working memory was not higher than the less proficient group. This finding brings us back to the notion that only those who have good command of both L1 and L2 can become good interpreters.

Findings from the present study suggest that working memory may be important for simultaneous interpretation but language proficiency perhaps assumes a more vital role in simultaneous interpreting performance.

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# APPENDIX A

## CHINESE AND ENGLISH DIGIT SPAN STIMULI

### Chinese

Four digits
1 7 2 9
3 5 6 7
9 2 0 4

Five digits
6 1 8 5 2
1 3 4 7 0
3 6 9 2 8

Six digits
2 4 7 0 1 8
9 5 6 7 3 0
1 6 4 2 7 5

Seven digits
3 7 5 1 6 0 8
2 1 6 0 9 7 5
5 0 7 2 3 1 4

Eight digits
7 9 6 3 2 5 0 4
1 3 7 8 4 6 2 5
9 4 6 1 3 8 5 0

Nine digits
8 2 6 7 4 0 1 3 5
6 3 4 0 8 9 2 5 7

4 9 1 2 7 3 0 8 5

Ten digits

6 0 3 8 5 2 4 9 7 1

7 1 4 2 9 6 8 5 3 0

2 6 3 1 7 8 5 0 9 4

**English**

Four digits

2 0 7 9

3 8 1 6

5 4 6 3

Five digits

8 9 4 0 2

1 5 8 3 7

6 3 9 5 2

Six digits

1 8 2 0 4 7

4 5 9 2 0 1

9 4 5 7 2 8

Seven digits

2 0 6 9 1 4 5

8 5 7 2 0 1 3

6 3 2 9 1 8 0

Eight digits

8 4 5 1 3 2 6 9

1 8 3 9 4 7 2 0

5 3 8 1 6 2 4 9

Nine digits

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 3 | 0 | 1 | 4 | 6 | 8 | 2 | 9 | 5 |
| 2 | 7 | 5 | 0 | 1 | 4 | 6 | 3 | 8 |
| 5 | 8 | 0 | 3 | 7 | 2 | 4 | 1 | 9 |

Ten digits

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 7 | 1 | 5 | 0 | 6 | 2 | 8 | 9 | 4 | 3 |
| 5 | 2 | 1 | 8 | 6 | 4 | 0 | 3 | 7 | 9 |
| 3 | 6 | 9 | 2 | 5 | 7 | 1 | 0 | 8 | 4 |

# APPENDIX B

## SENTENCES FOR CHINESE READING SPAN

Two Sentences (2.1)

1. 我一下班就回家，吃飽飯就開始看書。

2. 她從二十四歲起對企業經營產生興趣。

Two Sentences (2.2)

1. 我們應該用寬廣的立場來思考問題。

2. 哭是自然界一切動物所共有的本能。

Two Sentences (2.3)

1. 離開餐廳前，我給了他一筆不小的小費。

2. 這樣負面的想法無助於改善現況。

Three Sentences (3.2)

1. 因為心情不好，晚飯他一口都嚥不下。

2. 我們常會認為只有外國人才能做大師。

3. 每一位國民都應對國家大事表示關心。

Three Sentences (3.3)

1. 他走到她面前，大方的跟他打招呼。

2. 有好多大哲學家都富有幽默的機智。

3. 這傳聞雖真假難辨，眾人卻深信不疑。

Four Sentences (4.1)

1. 有的人把文化偶像的崇拜看作幼稚行為。

2. 同輩朋友中，他算是最早結婚的一個。

3. 寫和讀的關係，是一種天然的吐納關係。

4. 我今天完全不想涉及任何的現實政治。

Four Sentences (4.2)

1. 每個人的人生處境都是一個迷宮。

2. 鑑往知來，要預測未來就得認識過去。

3. 她認真回顧筆記，陷入沈思當中。

4. 恨令人產生懦弱，愛卻能產生勇敢。

Four Sentences (4.3)

1. 這位荷蘭來的外國人第一次到夜市。

2. 通過這次考試之後，一切便海闊天空。

3. 最近，我曾經在東南亞做過短暫的旅行。

4. 我已經領教了工作與社會究竟怎麼回事。

Five Sentences (5.1)

1. 沈湎於物質享受的人不會有高尚的理想。

2. 今日的世界，正義掃地，國際情勢漆黑。

3. 這件事雖然不容易辦，但我一定盡力去辦。

4. 亞洲國家目前學英文的人口是有增無減。

5. 到了重要的關頭，更應該看得清楚。

Five Sentences (5.2)

1. 克服自私與利害心，便可走上愛人的大路。

2. 大學教育在世界各地都有蓬勃的發展。

3. 最近上會上發生一個重大事件，造成不安。

4. 若要在職場上有競爭力，就必須眼光放遠。

5. 一旦財務情況不佳，學校就要對外募款。

Five Sentences (5.3)

1. 一個喜歡跳舞的人通常也會喜歡音樂。

2. 母校給予我的榮譽不單是個人榮譽。

3. 我上一次搬家，遺棄的書達五千餘冊。

4. 這種心情很可理解，但不必成為負累。

5. 大學生的閱讀資源，主要來自圖書館。

## APPENDIX C

## SENTENCES FOR ENGLISH READING SPAN

Two Sentences (2.1)

1. Sticking to my daily meal allowance of about 10 dollars will be tough.
2. Giving up pet ownership should be the last step an allergic person must take.

Two Sentences (2.2)

1. Some classrooms are so overcrowded that at exam time many students have to find seats elsewhere.
2. We are certain at this point that the actions taken have been appropriate.

Two Sentences (2.3)

1. Because their disease is associated with eating and inactivity, they routinely encounter less sympathy.
2. Coaches learned that athletic performance improved when athletes worked on endurance by running longer and longer distances.

Three Sentences (3.1)

1. Setting unrealistic goals only dooms you to failure, which fuels your stress levels.
2. The overwhelming majority of elementary schools still offer recess each day, usually for about 25 minutes.
3. The creative work of an artist does not lie in the signature on a painting.

Three Sentences (3.2)

1. Many people have introduced the study of acoustics through musical instrument demonstrations.
2. In addition to working with children, I often have my college students write poems about science.
3. What has impressed me most is the open-mindedness he displays as he progressed through the year.

Three Sentences (3.3)

1. Left to their own devices, children will naturally express themselves through music, dance, and visual arts.
2. With their arsenal of electronic gadgets, students these days find it easier to cheat.
3. When someone has the attitude that he knows best and acts accordingly, he marginalizes others.

Four Sentences (4.1)

1. By the time the chair had been turned around, the cat had made off for the courtyard.
2. Over the summer, the sunflower in my backyard grew into a plant of incredible beauty.
3. The cat became frightened and its white claws appeared from the cracks in its paws.
4. The two women got along together even though their personalities were as different as night and day.

Four Sentences (4.2)

1. The windows were all fogged up, except for a few patches someone had wiped clean.
2. I never expected that such an ordinary person might have such an impenetrable side to him.
3. For thousands of years human beings have communicated with one another in the language of gestures.
4. He was wearing a light green jacket with a hood hanging down in back.

Four Sentences (4.3)

1. Through the generosity of friends she was able to buy a small apartment in the city.
2. Karate is an art of self-defense that mainly relies on blows delivered with the hand.
3. The red paint on the wooden tables and benches was beginning to chip and wear.
4. A couple’s childbearing years are limited, but there is no such limit on adoption.

Five Sentences (5.1)

1. The telephones installed under the adjoining eaves have become private gathering places for teenagers.

2. As long as we are treated as equals, there is nothing we cannot discuss.
3. Although the city is filled with dust, its residents appear to be neat and tidy.
4. If you’re a good salesperson, the sky is the limit for you potential earnings.
5. From the smell in the cab one can tell whether the driver has just been smoking.

Five Sentences (5.2)

1. Today many households buy tissue paper in boxes by the dozen instead of by the box.
2. Remember in prayer the many who are sick in our church and community.
3. No one could figure out why he talked and acted so strangely during the last two years.
4. After years of abuse she freed herself and her children from this situation.
5. When Donna completed her studies with a master’s degree she was able to teach.

Five Sentences (5.3)

1. No one dared to disagree with him, so they hurriedly rushed to consent.
2. He was dressed in a sharp military uniform, facing the camera, saluting with his little hand.
3. It was the first time she had ever accepted these contradictions and thus was set free.
4. Once the true energy of our society has been released, state control will simply wither away.
5. The more I think about this, the more I see that everything comes down to politics.

## APPENDIX D

## SPEECH TEXT FOR SIMULTANEOUS INTERPRETATION

Thank you very much. Thanks for the introduction. Thank you for the warm welcome.

Mr. Chairman, dignitaries, ladies and gentlemen.

I'm glad to be back here. When I was a young governor, I came to Taiwan for four times between 1979 and 1988. I watched all the changes on this island. I watched your remarkable economic growth and your political growth. And I have watched the development of your democracy with great appreciation and admiration.

This foundation was formed to support and promote democracy, not only in Taiwan, but also around the world. That is important work, work that I try to advance in the late years I served as president. If I might, tonight I would like to put the growth of democracy within Taiwan in the larger context of what is going on in the $21^{st}$ century world and suggest some things that I think this Foundation could do beyond your borders to fulfill its mission.

In the 1990s, everyone knows we saw a remarkable growth in the globalization of the economy. We became more dependent on international trade and investment. There was an explosion in information technology. We began to cooperate in other ways, in unprecedented ways, in science and technology. In my last years of presidency, I was able to announce the sequencing of human genome, a project that succeeded because of amazing and unprecedented international scientific cooperation. We put a space station into the skies through international cooperation.

I can give many other examples but there were two other things that happened in the 1990s, particularly important to democracy which were often not noted in the press. First of all, in the decade of the 1990s, for the first time in all our human history, more than half of the people in this world were governed by those who they had voted for in free elections. And secondly, there was an explosion of civil society across the globe through non-governmental organizations now known everywhere as simply NGOs. Organizations which give people in rich countries poor countries alike a chance to pool their efforts as free people to change the lives of those within their concerns.

The 21st century, I believe, can be best summed up in a word, that is not globalization, because globalization has for most people been an economic meaning. I believe a better word is interdependence. For interdependence can be good or bad; or it can be good and bad. It simply means we can not escape each other. On September 11th 2001, the United States got a big shock of negative interdependence when the Al Qaeda terrorists killed three thousand people from 70 countries in the United States by using the forces of global interdependence open borders, easy travel, easy immigration, easy access to information and technology. Two hundred of those who died were also Muslims.

In the aftermath of the 9-11, I saw the forces of positive interdependence. My wife, who is now a US senator of New York, and I visited an elementary school in Manhattan where children have been forced out of their buildings by the damage of planes. There were 600 children there from over 80 different ethnic groups in one school. When I stood in line trying to console the family members of those who have been killed, I saw a man, a very large man about a head taller than me, with tears in his eyes, and I asked him if he has lost a family member. He said no. He had only come to offer his grief. I would never forget what he said. He said, "I'm an Egyptian and I'm a Muslim and I'm an American. And I'm afraid my fellow Americans will not trust me anymore because of what other people did. I hate them, more than you do."

He was an example of positive interdependence. In the Middle East, I have watched, when I was a president, as we had seven years of progress for peace. Then I watched four years of disintegration. In the four years of conflict, more than four times as many Israelis were killed by terrorists in the entire eight years I was president. But in the bad years, the Israelis and Palestinians were no less interdependent than they were in the good years. It just shifted from positive interdependence to negative interdependence. As you might imagine, even though I’m not president any more, I watched the events in China and in Taiwan and the relationship between the two very closely. There was an amazing article in the British magazine, the Economist, a couple of weeks ago pointing out the explosively increasing economic ties between the two, saying that more than ten million people on mainland China now work for companies owned by Taiwanese people. I noted that there have been some direct air flights recently. So I see continuing negative tension over political differences and positive economic and personal contact.

What does all this tell us about the world we are living in? We can not escape each other. China and Taiwan, the Israelis and Palestinians, the Catholics and Protestants in Northern Ireland, the different ethnic groups in Bosnia, in Kosovo, the Tamils and the Buddhists in Sri Lanka, the Muslims, the Acheh separatists, and the main government in Thailand and in Indonesia. All these things we are seeing, positive or negative, going on in the world remind us we can not escape each other. Therefore I believe that the great challenge of the 21st century is to move from an interdependent but unstable world to more integrated communities in which we share. We share responsibilities. We share benefits and we share basic values. Every person matters and there is a chance. Every person has a responsible role to fill in this society. Competition is good but we all do better when we work together. Our differences are important. They make life interesting and they matter but our common humanity matters more.

How can we move from an interdependent to an integrated world? I will suggest five things. First of all, we must fight the enemies of integrated communities. We must reduce terror and war and the threat of weapons of mass destruction. Second, we must build the world with more partners and fewer enemies by bringing the benefits of globalization to the fifty percent of human beings on the earth who have not received them.

I was driving through the streets of Taipei on the way to the speech tonight, thinking about the very first time that I came here more than twenty-five years ago; thinking about how the city had changed; thinking about how a small number of people have built almost three hundred billion dollars in cash reserves and companies that sustained the globe and a vibrant, political and educational as well as economic system. And it was almost impossible to remember that tonight, half the world's people live on two dollars a day or less. A billion people live on less than a dollar a day. A billion people would go to bed hungry tonight. One in four people have no access to clean water. One in 4 people who die on earth all over the world this year from all causes natural and manmade will die of Aids, TB, malaria and infections related to diarrhea. Most of them are little children who never got a clean glass of water. Ten million children die every year of completely preventable childhood diseases. 130 million children on earth never go to school a single day.

We must bring them into the system that has been so good for you, for all of Asia, for the United States. There are lots of things we can do. We know it wouldn't cost much money to put all the children in the world in school and would have the benefit of taking them out of the jobs that their parents could then fill. We know we could speed economic development of many poor nations if we also combat the challenge of global warming and develop a whole new energy economy based on solar energy, wind energy, energy conservation technologies and other energy options that are out there now. There is a one-trillion-dollar untapped market in clean energy and energy conservation technologies waiting to be born that would have the corollary benefits of making it easier for very poor countries to develop economically much more quickly.

The third thing we have to do is to build institutions of sharing and cooperation at every level. The strength in the global ones like the United Nations, the World Bank, the International Monetary Fund, is to support regional cooperation through things like the European Union or APEC or ASEAN or any number of other regional groups that are forming around the world, and to support national cooperation by helping the new democracies, not simply to have honest elections but to have honest governments that are also capable governments, and here is what I think your foundation could make a big difference.

I spent a lot of time to date working in the former Soviet Union. I'm going in the two countries with my eighth project or the Caribbean, which is relatively poor, which has a big Aids problem right on the America's backdoor. I go to Latin America a lot where the per capita income is very dramatically low, and I work in Africa where most of the countries with big Aids problems also have income of less than a dollar a day.

In the places where I go, there is always an elected president who won a fair election but very often these presidents who won fair elections can sit in their offices and issue orders and nothing happens. Very often newly elected parliaments like you, Mr. Speaker, they pass laws but nothing happens because they don't have the organized institutions that carry out the laws are the executive officers, orders of the President or the Prime Minister. They do not have the institutional capacity to translate the benefits of human freedom expressed in elections into the lives of the people who are voted and this is one of the most ignored problem in the twenty-first century world and so I have decided to spend quite a bit of the rest of my life, trying to figure out how to do this work. It never grabs the headlines. It's not so interesting figuring out how to pass transparent legislation or a property right legislation or build the bureaucracy for this or that or the other department. But unless you have a government that functions, people lose faith in democracy.

I belong to a group of former heads of government and heads of state called the Club of Madrid. And a couple of years ago, we had a meeting and we weren't sure many people would come and basically it was about building the effectiveness of democratic government. It wasn’t an inflammatory topic. It wasn't a controversial topic. We were mobbed by leaders of governments of these new democracies who came to us honestly saying that there were people who have lived under repression for so long, so these people want an election and they couldn't get anything done for them because they had no institutional capacity to advance the public interest. So it's something that I think maybe you should look at because your powers of organization in delivery are legendary as you know.

Finally, I think we have to strengthen the strength of this nongovernmental organization movement around the world. You mentioned that I was working in Tsunami-affected areas. One of the most interesting things about my new job is that I have to coordinate all the work being done by the home governments, the international organizations, the national agencies that are helping like USAID and hundreds of NGOs, literally hundreds of them from all over the world. But this is a good thing. So we have to reduce the threats to interdependence, make the world with more partners and fewer enemies, increase institutional cooperation.

# APPENDIX E

## LANGUAGE BACKGROUND QUESTIONNAIRE

ID:___________ Name:____________________ Gender: M / F Age: _________

Country of Birth:________________ Length of Stay in U.S.:______ months or _____years.

Do you know any languages other than English?__________________________(specify)

What is your first language, i.e. what you learned to speak first? (If more than one was learned simultaneously, state all):_____________________________________________

Please list all the languages you know and/or have studied and for each, please indicate when you were first exposed to the language, (0-4 yrs, 5-8 yrs, 9-12 yrs, >12) and when you developed functional fluency in it (if you did). Also indicate the context of exposure: at home only, at home and school, at school only; some other context (specify)

| Language | Context of Exposure (at home, at school…etc) | Age at Exposure (0-4 yrs, 5-8 yrs, 9-12 yrs, or >12) | Age at Mastery (0-4 yrs, 5-8 yrs, 9-12 yrs, or > 12) |
|---|---|---|---|
| | | | |
| | | | |
| | | | |
| | | | |

What was/is the language of instruction in your:

a. Elementary School _________
b. Middle School ____________
c. High School ___________
d. College ___________

What language(s) do you mostly use when speaking with each of the following: (If you use more than one language equally often, indicate that)

a. Your Parents ____________
b. Siblings ____________
c. Grandparents ____________
d. Friends ____________
e. Classmates _____________
f. Co-workers _____________
g. Partner _____________
h. Other (specify) _____________

In which language do you feel you can communicate most effectively? (If more than one, list all)

________________________________________________________________________

Circle one: “When speaking with other bilinguals I switch between languages during a conversation:”

Never Rarely Sometimes Frequently All the time Not Applicable

Please rate your language ability in English and your other language (specify) on a 7 point scale where 1= very little knowledge and 7= use it like a native speaker:

| | | |
|---|---|---|
| Language: English | Language: _________ | Language: ___________ |
| Speak English ___________ | Speak ___________ | Speak_____________ |
| Read English _____________ | Read _____________ | Read ______________ |
| Write English _____________ | Write _____________ | Write ______________ |
| Understand English _________ | Understand ___________ | Understand _________ |

TOEFL _________

# APPENDIX F

# CONSENT FORM

**Effects of Working Memory, Language Proficiency, and Training on Simultaneous Interpretation Performance**

You have been asked to participate in a research study on the effects of working memory, language proficiency, and training on simultaneous interpretation performance. You were selected to be a possible participant because you are a bilingual with Mandarin as your native language and English as your second language. A total of 60 people have been asked to participate in this study. The purpose of this study is to examine how short term memory, language proficiency in native and second language, and training affect Mandarin-English bilinguals' performance in simultaneous interpretation (SI).

If you agree to participate in this study, you will be asked to perform a series of recall and reaction speed tasks in front of a computer and will interpret a spoken text from English into Mandarin. Your performance on these tasks will be recorded by a computer and a tape recorder (for the SI task). In addition, you will also be asked to fill out a short language background questionnaire. The duration of the entire study will be two hours. There are no risks associated with this study.

You will receive $15 in compensation or course credit for your participation in the study. The study is confidential and your name and responses on the written questionnaire will be kept confidential. All computer and tape-recorded responses will be coded and the audio tapes used in the study will be securely stored at the residence of the researcher. Your participation in this study is voluntary and you are free to withdraw from the study at any time without any penalty. Your decision whether or not to participate will not affect your current or future relations with Texas A&M University. If you decide to participate, you are free to refuse to answer any of the questions that may make you uncomfortable. You can contact Yeh-Zu Tzou with any questions about this study.

This research study has been reviewed by the Institutional Review Board – Human Subjects in Research, Texas A&M University. For research-related problems or questions regarding subjects' rights, you can contact the Institutional Review Board through Ms. Melissa McIlhaney, IRB Program Coordinator, Office of Research Compliance, (979)4584067. Please be sure you have read the above information, asked questions and received answers to your satisfaction. You will be given a copy of the consent form for you records. By signing this document, you consent to participate in the study.

Participant’s Signature and Date:________________________________

Principal Investigator’s Signature and Date:___________________________________

# APPENDIX G

## READING SPAN ANSWER SHEET

**Chinese Reading Span** **Participant ID:**

________ ________
________ ________
________ ________

________ ________ ________
________ ________ ________
________ ________ ________

________ ________ ________ ________
________ ________ ________ ________
________ ________ ________ ________

________ ________ ________ ________ ________
________ ________ ________ ________ ________
________ ________ ________ ________ ________

**English Reading Span**

________ ________
________ ________
________ ________

________ ________ ________
________ ________ ________
________ ________ ________

________ ________ ________ ________

# APPENDIX H

## ANOVA TABLES FOR THE THREE GROUPS' WM

Digit Span

Tests of Within-Subjects Effects

| Source | | Type III Sum of Squares | df | Mean Square | F | Sig. | Partial Eta Squared | Noncent. Parameter | Observed Power(a) |
|---|---|---|---|---|---|---|---|---|---|
| Language | Sphericity Assumed | 143.12 | 1 | 143.12 | 177.13 | .000 | .843 | 177.129 | 1.000 |
| | Greenhouse-Geisser | 143.12 | 1.000 | 143.12 | 177.13 | .000 | .843 | 177.129 | 1.000 |
| | Huynh-Feldt | 143.12 | 1.000 | 143.12 | 177.13 | .000 | .843 | 177.129 | 1.000 |
| | Lower-bound | 143.12 | 1.000 | 143.12 | 177.13 | .000 | .843 | 177.129 | 1.000 |
| Language* Group | Sphericity Assumed | .115 | 2 | .057 | .071 | .932 | .004 | .142 | .060 |
| | Greenhouse-Geisser | .115 | 2.000 | .057 | .071 | .932 | .004 | .142 | .060 |
| | Huynh-Feldt | .115 | 2.000 | .057 | .071 | .932 | .004 | .142 | .060 |
| | Lower-bound | .115 | 2.000 | .057 | .071 | .932 | .004 | .142 | .060 |
| Error (Language) | Sphericity Assumed | 26.663 | 33 | .808 | | | | | |
| | Greenhouse-Geisser | 26.663 | 33.000 | .808 | | | | | |
| | Huynh-Feldt | 26.663 | 33.000 | .808 | | | | | |
| | Lower-bound | 26.663 | 33.000 | .808 | | | | | |

a Computed using alpha = .05

Tests of Between-Subjects Effects

| Source | Type III Sum of Squares | df | Mean Square | F | Sig. | Partial Eta Squared | Noncent. Parameter | Observed Power(a) |
|---|---|---|---|---|---|---|---|---|
| Intercept | 2941.765 | 1 | 2941.765 | 1935.83 | .000 | .983 | 1935.833 | 1.000 |
| Group | 14.796 | 2 | 7.398 | 4.868 | .014 | .228 | 9.737 | .765 |
| Error | 50.148 | 33 | 1.520 | | | | | |

a Computed using alpha = .05

## Reading Span

**Tests of Within-Subjects Effects**

Measure: MEASURE_1

| Source | | Type III Sum of Squares | df | Mean Square | F | Sig. | Partial Eta Squared | Noncent. Parameter | Observed Power(a) |
|---|---|---|---|---|---|---|---|---|---|
| Language | Sphericity Assumed | 307.461 | 1 | 307.46 | 32.599 | .000 | .497 | 32.599 | 1.000 |
| | Greenhouse-Geisser | 307.461 | 1.000 | 307.46 | 32.599 | .000 | .497 | 32.599 | 1.000 |
| | Huynh-Feldt | 307.461 | 1.000 | 307.46 | 32.599 | .000 | .497 | 32.599 | 1.000 |
| | Lower-bound | 307.461 | 1.000 | 307.46 | 32.599 | .000 | .497 | 32.599 | 1.000 |
| Language * Group | Sphericity Assumed | 46.581 | 2 | 23.290 | 2.469 | .100 | .130 | 4.939 | .461 |
| | Greenhouse-Geisser | 46.581 | 2.000 | 23.290 | 2.469 | .100 | .130 | 4.939 | .461 |
| | Huynh-Feldt | 46.581 | 2.000 | 23.290 | 2.469 | .100 | .130 | 4.939 | .461 |
| | Lower-bound | 46.581 | 2.000 | 23.290 | 2.469 | .100 | .130 | 4.939 | .461 |
| Error (Language) | Sphericity Assumed | 311.239 | 33 | 9.431 | | | | | |
| | Greenhouse-Geisser | 311.239 | 33.000 | 9.431 | | | | | |
| | Huynh-Feldt | 311.239 | 33.000 | 9.431 | | | | | |
| | Lower-bound | 311.239 | 33.000 | 9.431 | | | | | |

a Computed using alpha = .05

**Tests of Between-Subjects Effects**

| Source | Type III Sum of Squares | df | Mean Square | F | Sig. | Partial Eta Squared | Noncent. Parameter | Observed Power(a) |
|---|---|---|---|---|---|---|---|---|
| Intercept | 63507.719 | 1 | 63507.72 | 1924.66 | .000 | .983 | 1924.655 | 1.000 |
| Group | 444.476 | 2 | 222.238 | 6.735 | .004 | .290 | 13.470 | .891 |
| Error | 1088.899 | 33 | 32.997 | | | | | |

a Computed using alpha = .05

# APPENDIX I

## ANOVA TABLES FOR THE THREE GROUPS' SI-T and SI-A

ANOVA

SIT

| | Sum of Squares | df | Mean Square | F | Sig. | $\eta_p^2$ | 1-β |
|---|---|---|---|---|---|---|---|
| Between Groups | 1771.336 | 2 | 885.668 | 85.456 | .000 | .838 | 1 |
| Within Groups | 342.011 | 33 | 10.364 | | | | |
| Total | 2113.347 | 35 | | | | | |

ANOVA

SIA

| | Sum of Squares | df | Mean Square | F | Sig. | $\eta_p^2$ | 1-β |
|---|---|---|---|---|---|---|---|
| Between Groups | 40.905 | 2 | 20.452 | 73.825 | .000 | .817 | 1 |
| Within Groups | 9.142 | 33 | .277 | | | | |
| Total | 50.047 | 35 | | | | | |

# APPENDIX J

## T-TEST RESULTS FOR TWO PROFICIENCY GROUPS' L1 AND L2 READING TIME AND LANGUAGE SKILL SELF-EVALUATION

Independent Samples Test

| | | Levene's Test for Equality of Variances | | t-test for Equality of Means | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | F | Sig. | t | Df | Sig. (2-tailed) | Mean Diff. | Std. Error Diff. | 95% Confidence Interval of the Difference | |
| | | | | | | | | | Lower | Upper |
| Chinese Reading Time | Equal variances assumed | 1.118 | .298 | .273 | 34 | .787 | 38.59 | 141.47 | -248.91 | 326.099 |
| | Equal variances not assumed | | | .253 | 18.33 | .803 | 38.59 | 152.4 | -281.17 | 358.355 |
| English Reading Time | Equal variances assumed | 5.626 | .023 | -3.63 | 34 | .001 | -952.57 | 262.24 | -1485.5 | -419.638 |
| | Equal variances not assumed | | | -4.47 | 33.98 | .000 | -952.57 | 213.22 | -1385.908 | -519.237 |
| Chinese Self-Evaluation | Equal variances assumed | .439 | .512 | -.57 | 34 | .573 | -.250 | .44 | -1.143 | .643 |
| | Equal variances not | | | -.57 | 22.39 | .573 | -.250 | .44 | -1.156 | .656 |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | assumed | | | | | | | | | |
| English Self Evaluation | Equal variances assumed | .110 | .743 | 3.65 | 34 | .001 | 2.88 | .79 | 1.273 | 4.477 |
| | Equal variances not assumed | | | 3.86 | 25.69 | .001 | 2.88 | .75 | 1.342 | 4.407 |

# APPENDIX K

## T-TEST RESULTS FOR TWO PROFICIENCY GROUPS' TOEFL SCORES

Independent Samples Test

| | | Levene's Test for Equality of Variances | | t-test for Equality of Means | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | F | Sig. | t | df | Sig. (2-tailed) | Mean Difference | Std. Error Difference | 95% Confidence Interval of the Difference | |
| | | | | | | | | | Lower | Upper |
| TOEFL | Equal variances assumed | 8.203 | .008 | 2.398 | 30 | .023 | 38.766 | 16.168 | 5.748 | 71.79 |
| | Equal variances not assumed | | | 3.178 | 25.205 | .004 | 38.766 | 12.198 | 13.653 | 63.88 |

# APPENDIX L

## ANOVA TABLES FOR THE TWO PROFICIENCY GROUPS' WM

Digit Span

Tests of Within-Subjects Effects

| Source | | Type III Sum of Squares | df | Mean Square | F | Sig. | Partial Eta Squared | Noncent. Parameter | Observed Power(a) |
|---|---|---|---|---|---|---|---|---|---|
| Language | Sphericity Assumed | 142.007 | 1 | 142.007 | 188.57 | .000 | .847 | 188.572 | 1.000 |
| | Greenhouse-Geisser | 142.007 | 1.000 | 142.007 | 188.57 | .000 | .847 | 188.572 | 1.000 |
| | Huynh-Feldt | 142.007 | 1.000 | 142.007 | 188.57 | .000 | .847 | 188.572 | 1.000 |
| | Lower-bound | 142.007 | 1.000 | 142.007 | 188.57 | .000 | .847 | 188.572 | 1.000 |
| Language * Proficiency Group | Sphericity Assumed | 1.174 | 1 | 1.174 | 1.558 | .220 | .044 | 1.558 | .228 |
| | Greenhouse-Geisser | 1.174 | 1.000 | 1.174 | 1.558 | .220 | .044 | 1.558 | .228 |
| | Huynh-Feldt | 1.174 | 1.000 | 1.174 | 1.558 | .220 | .044 | 1.558 | .228 |
| | Lower-bound | 1.174 | 1.000 | 1.174 | 1.558 | .220 | .044 | 1.558 | .228 |
| Error (Language) | Sphericity Assumed | 25.604 | 34 | .753 | | | | | |
| | Greenhouse-Geisser | 25.604 | 34.000 | .753 | | | | | |
| | Huynh-Feldt | 25.604 | 34.000 | .753 | | | | | |
| | Lower-bound | 25.604 | 34.000 | .753 | | | | | |

a Computed using alpha = .05

**Tests of Between-Subjects Effects**

| Source | Type III Sum of Squares | df | Mean Square | F | Sig. | Partial Eta Squared | Noncent. Parameter | Observed Power(a) |
|---|---|---|---|---|---|---|---|---|
| Intercept | 2782.563 | 1 | 2782.563 | 1676.317 | .000 | .980 | 1676.317 | 1.000 |
| Proficiency Group | 8.507 | 1 | 8.507 | 5.125 | .030 | .131 | 5.125 | .595 |
| Error | 56.438 | 34 | 1.660 | | | | | |

a Computed using alpha = .05

## Reading Span

**Tests of Within-Subjects Effects**

| Source | | Type III Sum of Squares | df | Mean Square | F | Sig. | Partial Eta Squared | Noncent. Parameter | Observed Power(a) |
|---|---|---|---|---|---|---|---|---|---|
| Language | Sphericity Assumed | 277.778 | 1 | 277.778 | 26.601 | .000 | .439 | 26.601 | .999 |
| | Greenhouse-Geisser | 277.778 | 1.000 | 277.778 | 26.601 | .000 | .439 | 26.601 | .999 |
| | Huynh-Feldt | 277.778 | 1.000 | 277.778 | 26.601 | .000 | .439 | 26.601 | .999 |
| | Lower-bound | 277.778 | 1.000 | 277.778 | 26.601 | .000 | .439 | 26.601 | .999 |
| Language * Proficiency Group | Sphericity Assumed | 2.778 | 1 | 2.778 | .266 | .609 | .008 | .266 | .079 |
| | Greenhouse-Geisser | 2.778 | 1.000 | 2.778 | .266 | .609 | .008 | .266 | .079 |
| | Huynh-Feldt | 2.778 | 1.000 | 2.778 | .266 | .609 | .008 | .266 | .079 |
| | Lower-bound | 2.778 | 1.000 | 2.778 | .266 | .609 | .008 | .266 | .079 |
| Error (Language) | Sphericity Assumed | 355.042 | 34 | 10.442 | | | | | |
| | Greenhouse-Geisser | 355.042 | 34.000 | 10.442 | | | | | |
| | Huynh-Feldt | 355.042 | 34.000 | 10.442 | | | | | |
| | Lower-bound | 355.042 | 34.000 | 10.442 | | | | | |

a Computed using alpha = .05

**Tests of Between-Subjects Effects**

| Source | Type III Sum of Squares | df | Mean Square | F | Sig. | Partial Eta Squared | Noncent. Parameter | Observed Power(a) |
|---|---|---|---|---|---|---|---|---|
| Intercept | 59698.778 | 1 | 59698.79 | 1517.718 | .000 | .978 | 1517.718 | 1.000 |
| Proficiency Group | 196.000 | 1 | 196.000 | 4.983 | .032 | .128 | 4.983 | .583 |
| Error | 1337.375 | 34 | 39.335 | | | | | |

a Computed using alpha = .05

# APPENDIX M

## ANOVA TABLES FOR THE TWO PROFICIENCY GROUPS' SI-T and SI-A

ANOVA

SIT

| | Sum of Squares | Df | Mean Square | F | Sig. | $\eta_p^2$ | 1-β |
|---|---|---|---|---|---|---|---|
| Between Groups | 418.087 | 1 | 418.087 | 8.385 | .007 | .197 | .65 |
| Within Groups | 1695.260 | 34 | 49.861 | | | | |
| Total | 2113.347 | 35 | | | | | |

ANOVA

SIA

| | Sum of Squares | Df | Mean Square | F | Sig. | $\eta_p^2$ | 1-β |
|---|---|---|---|---|---|---|---|
| Between Groups | 8.000 | 1 | 8.000 | 6.469 | .016 | .159 | .50 |
| Within Groups | 42.047 | 34 | 1.237 | | | | |
| Total | 50.047 | 35 | | | | | |

# VITA

Yeh-Zu Tzou received her Bachelor of Arts degree in Foreign Languages and Literatures from the National Taiwan University in 1997. She entered the Graduate School of Translation and Interpretation at the Monterey Institute of International Studies in September 1998 and received her Master of Arts degree in Translation and Interpretation in May 2000. Her research interests include studies in interpretation and translation. She also has a keen interest in bilingual and English as a second language education.

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