John Benjamins Publishing Company

This is a contribution from *Psycholinguistic and Cognitive Inquiries into Translation and Interpreting*.
Edited by Aline Ferreira and John W. Schwieter.
© 2015. John Benjamins Publishing Company

This electronic file may not be altered in any way.
The author(s) of this article is/are permitted to use this PDF file to generate printed copies to be used by way of offprints, for their personal use only.
Permission is granted by the publishers to post this file on a closed server which is accessible to members (students and staff) only of the author's/s' institute, it is not permitted to post this PDF on the open internet.
For any other use of this material prior written permission should be obtained from the publishers or through the Copyright Clearance Center (for USA: www.copyright.com).
Please contact rights@benjamins.nl or consult our website: www.benjamins.com

Tables of Contents, abstracts and guidelines are available at www.benjamins.com

CHAPTER 5

Simultaneous interpreting and working memory capacity

Šárka Timarová*, Ivana Čeňková**, Reine Meylaerts*, Erik Hertog*, Arnaud Szmalec***, and Wouter Duyck****
*K.U. Leuven, Belgium / **Charles University in Prague, Czech Republic / ***Université Catholique de Louvain, Belgium / ****Ghent University, Belgium

The aim of the present exploratory correlational study was to test whether a relationship exists between working memory capacity (WMC) and simultaneous interpreting (SI) performance measures in a sample of professional interpreters. Twenty-eight professional interpreters, aged 25–55, were tested on WMC tasks (letter span, Corsi task, complex span) and on several measures of SI (lexical, semantic and syntactic processing, temporal delay, vocabulary richness and dealing with speed). Additionally, general cognitive ability, age and interpreting experience were considered. There are two main findings. First, WMC in this sample shows predictable patterns in the structure of interpreters' working memory: there was a dissociation between verbal and spatial memory and a negative relationship between age on the one hand and WMC and general cognitive ability on the other. This negative relationship goes against the hypothesis of WMC enlargement with interpreting experience. Secondly, WMC measures were only marginally significantly related to SI measures, and then only to those which have a predictable high memory component, such as figures and lists of nouns. The results suggest that WMC, where the focus is on storage and maintenance, may not be as important for professional SI as previously thought.

1. Introduction and background

Working memory is probably the single most often researched isolated cognitive component in interpreting studies. The primary theoretical starting point has been the multimodal working memory model by Baddeley and Hitch (1974), although more recent work considers other models, too. More specifically, Cowan's (1988) model of activated long-term memory (Mizuno 2005) and Ericsson and Kintsch's (1995) long-term working memory models (Pöchhacker 2004) were suggested as being useful in the context of interpreting. Additionally, the role of working

DOI 10.1075/btl.115.05tim
© 2015 John Benjamins Publishing Company

memory was modelled in several models of the interpreting process (for a review of general cognitive and interpreting-specific working memory models, see Timarová 2008). The first empirical studies dedicated to interpreters' working memory date back to the 1990s (Darò and Fabbro 1994; Padilla et al. 1995), although an interest in interpreters' working memory goes back to early interpreting research and theories. Seleskovitch (1968/1978) considered excellent memory to be the cornerstone of interpreting, and Gerver (1975) built his interpreting process model around short-term memory stores. Good working memory came to be considered the very basis of the interpreting skill (Bajo et al. 2000; Darò 1989). Empirical research has therefore mostly focused on comparing working memory between interpreters and non-interpreters (interpreting students, untrained bilinguals) in search of evidence that interpreters' working memory capacity is larger than that of non-interpreters (Christoffels et al. 2006; Padilla et al. 1995). A subgroup of studies (e.g. Chincotta and Underwood 1998; Köpke and Nespoulous 2006; Padilla et al. 2005) focused on a specific component of working memory, the phonological loop (Baddeley and Hitch 1974), and the way storage is disrupted through concurrent articulation. The assumption behind all these studies is that if interpreters can be shown to have better working memory than individuals with similar background (education, bilingualism, age), then better memory could be attributed to interpreting. If this advantage held for comparison of professional interpreters to interpreting students, then better working memory would be the result of extensive practice rather than aptitude. This is the basic rationale behind the majority of working memory studies conducted to date.

The general approach has been to compare interpreters to control groups on a variety of working memory tasks (Chincotta and Underwood 1998; Christoffels et al. 2006; Köpke and Nespoulous 2006; Liu et al. 2004; Nordet and Voegtlin 1998; Padilla et al. 1995; Signorelli et al. 2012; Timarová 2007; Tzou et al. 2012). The overall broad conclusion is that interpreters do not seem to outperform interpreting students and control bilinguals on simple storage tasks (short-term memory tasks, such as the digit span and its variants) where only memorising and a subsequent recall are required. While some studies did report evidence in favour of interpreters' better performance, these findings are sometimes qualified by methodological or reporting parameters. On the basis of an extensive analysis, Köpke and colleagues concluded that "maintenance rehearsal [i.e. memorising – our note] […] probably plays only a minor role in expert interpreting" (Köpke and Signorelli 2012, 195, also Köpke and Nespoulous 2006). Tasks combining storage and processing, on the other hand, provided more support for the hypothesis of better working memory in interpreters. These tasks, now viewed as a measure of working memory as opposed to short-term memory (see e.g. Engle et al. 1999), include the reading span (Daneman and Carpenter 1980) and its variant, the listening span

© 2015. John Benjamins Publishing Company
All rights reserved

(ibid). In such tasks, storage and recall are combined with a simple processing task. The majority of studies found an advantage in interpreters, although here too methodological decisions with regard to participants, materials or procedure may play a role. Additionally, interesting evidence comes from the study of the effect of articulatory suppression on interpreters' recall. Articulatory suppression is a condition where participants are required to memorise a series of stimuli, while engaging their voice, e.g., by repeating *la-la-la*. Such vocalisation disrupts the process of refreshing the memory trace and negatively affects recall. While interpreters did not differ from non-interpreters on recall under normal conditions, they tended to be less affected by simultaneously speaking than non-interpreters (Chincotta and Underwood 1998; Köpke and Nespoulous 2006; Padilla et al. 2005; Shlesinger 2000). These findings are, however, so far limited to untrained individuals, interpreting students and interpreters with fairly limited professional experience. One study (Christoffels 2004) related resistance to articulatory suppression to better performance in interpreting in untrained bilinguals, which raises another question: regardless of the superiority or otherwise of working memory in interpreters, is there a relationship between working memory and interpreting performance?

This question was addressed by a second strand of research. Very interestingly, the studies lend themselves to a useful comparison on the basis of skill level. Christoffels (2004) tested untrained bilinguals, Tzou et al. (2012) compared interpreting students and untrained bilinguals, Hodáková (2009) tested interpreting students, and Liu (2001) compared interpreting students and professional interpreters. That means that among the four studies, the full range of interpreting experience, from untrained bilinguals to professional interpreters, was submitted to a test. Table 1 provides an overview of the main design features and results.

Table 1. Relation between working memory and simultaneous interpreting at different skill levels.

	Untrained	**Untrained + Students**	**Students**	**Students + Professionals**
Study	Christoffels, 2004	Tzou et al., 2012	Hodáková, 2009	Liu, 2001
Test WM	digit span reading span articulatory suppression test	digit span reading span	listening span arithmetic addition attention	listening span
Test SI	accuracy of selected sentences + overall quality	accuracy of selected sentences + overall quality	accuracy of idea units	accuracy of idea units
Relationship between WM and SI found?	Yes	Yes	Yes	No

© 2015. John Benjamins Publishing Company
All rights reserved

In two separate experiments, Christoffels (2004) tested a group of untrained bilingual students on a digit span task, reading span task and a test of articulatory suppression effect. The participants also performed a simultaneous interpreting task consisting of a short text from English into Dutch (from their second language to their mother tongue). The interpretation was scored in two ways: selected sentences were scored for their accuracy, and an overall assessment of the interpretation was made (only the first measure was used in the experiment involving articulatory suppression). Christoffels found positive correlation for all measures. Higher resistance to articulatory suppression was associated with better performance in the interpreting task. Digit span correlated positively with both measures of interpreting (selected sentences and overall quality) and reading span correlated positively with accuracy of selected sentences. Tzou et al. (2012) tested three groups of Chinese – English bilingual participants: untrained bilinguals, interpreting students in their first year of training and interpreting students in their second year of training. They too administered a digit span and a reading span task (in both English and Chinese), and measured simultaneous interpreting performance in the same way as Christoffels on selected segments and on overall quality. Tzou et al. report that both measures of simultaneous interpreting correlated positively with the English and Chinese reading span, and the English digit span.

Hodáková (2009) tested a large group of beginning and advanced interpreting students and compared their performance on a listening span task, a test of simple arithmetic addition, a test of attention, and consecutive and simultaneous interpreting (German – Slovak). She found a correlation between the listening span and consecutive interpreting and between the arithmetic addition test and simultaneous interpreting. The attention test was not related to either interpreting mode. Finally, Liu (2001) tested three groups of Chinese-English interpreters: beginning and advanced interpreting students and experienced professionals. The listening span test was used as a measure of working memory, and the three groups performed very similarly on the test, with no significant differences found. On the simultaneous interpreting task, Liu administered several texts and measured accuracy of selected manipulated segments. Each participant interpreted a total of 12 experimental texts (three different texts, each containing a segment consisting of essential and secondary idea units, followed by a continuation sentence, in an easy and difficult version). Liu measured two variables: correctly interpreted idea units and correctly interpreted continuation sentences as a function of importance, difficulty, speed and interpreting experience. Most importantly for our analysis, Liu found significant differences between the groups on the number of idea units correctly interpreted, with professional interpreters achieving higher score than students on the total number of units, but interpreters were not less

© 2015. John Benjamins Publishing Company
All rights reserved

affected by speed or difficulty. Liu's conclusion was that the observed differences in simultaneous interpreting, both quantitative (more segments correctly interpreted by professionals) and qualitative (better selection of essential over secondary idea units), cannot be attributed to general cognitive ability, as the groups performed equally on the listening span test, and that interpreters must therefore draw on task-specific skills and strategies (Liu et al., 2004:36).

Taking the four studies together, a relationship between working memory and simultaneous interpreting was found in three of them – in untrained bilinguals and interpreting students, but not in professional interpreters. The finding that working memory is a predictor at lower levels of acquired skill is consistent with literature on skill acquisition (Ackerman 1988), whereby working memory plays an important role during the process of acquisition, where automatic routines have not yet been established. A relationship between working memory and simultaneous interpreting in professional interpreters was tested in one study and was not demonstrated. However, Liu did not make a direct comparison of participants' working memory and simultaneous interpreting.

In a study with a similar design, Hermans et al. (2007) tested experienced sign-language interpreters (spoken Dutch – Dutch sign-language) and sign-language interpreting students. Like Liu (2001), they found no differences between the two groups on tests of general cognitive ability, including short-term memory, working memory and cognitive control, but a significant difference on the interpreting tasks. When, however, interpreting experience was ignored, and individual performance on the cognitive tests was correlated with performance on the interpreting measures, a relationship between working memory and interpreting was found. Such results indicate that while the *group* performance may not differ, when *individual* performance is taken into account, relationships exist.

Another interesting and important finding is that the digit span task was predictive of interpreting performance, although short-term memory measures do not provide a clear-cut evidence of superior working memory in interpreters. That leads us to the following questions: 1. Is there a relationship between working memory and simultaneous interpreting in professional interpreters? 2. Can a relationship be found at the level of capacity tasks, which do not show reliable superiority of interpreters in comparison to other populations?

© 2015. John Benjamins Publishing Company
All rights reserved

2. Method

2.1 Design

The study was designed as an exploratory descriptive (correlational) study. A group of professional simultaneous interpreters was tested on two types of tasks: (a) a battery of working memory capacity and general cognitive ability tests (4 tests); (b) realistic simultaneous interpreting tasks (8 measures). Performance on the two types of tasks was correlated to test for relationships.

2.2 Participants

A total of 28 participants were recruited for the study. All participants were professional interpreters accredited to work for the institutions of the European Union. The participant's mother tongue was either Czech or Dutch and their professional (accredited) language combination included English. The participating group consisted of 18 females and 10 males. There were 20 interpreters with Czech as their mother tongue (15 females) and 8 interpreters with Dutch as their mother tongue (3 females). The mean age of the participants was 37.1 years (SD = 8.2 years), ranging from 25 to 55 years. All participants completed university-level education beyond bachelor level, i.e. achieved a degree which formally takes four or more years of education. Twenty-three participants were formally trained as interpreters, 5 participants had no formal training.[1] All participants were active interpreters at the time of testing and interpreting was their main professional activity, either as staff interpreters at one of the EU institutions (European Commission, European Parliament) or as freelance interpreters for the same institutions (and possible further activity on the private market). Professional interpreting experience ranged from one to 25 years, with M = 11.9 years (SD = 6.9 years). Since professional activity in a year varies, participants were also asked to estimate the number of days they work per each year of their professional career, which were added up to provide an estimate of the total number of days worked. The mean professional experience in number of days was M = 1457 days (SD = 1075 days).[2] Participants' mean subjective rating of English comprehension was M = 9.2 (out

1. Eligibility criteria allow the EU inter-institutional interpreting test to be open to individuals with formal training and no experience, or to individuals without formal training but proven professional experience.

2. Interpreters in this sample who had no formal training in interpreting were among the most experienced ones in this sample, with the mean number of years M = 19.0 years (SD = 4.2 years).

© 2015. John Benjamins Publishing Company
All rights reserved

of 10; SD = 1.1). The mean age of English acquisition (i.e. when participants first started learning English, either formally or informally) was M = 11 years (SD = 3 years). Twenty-five participants interpret from English every time they work. The mean estimated proportion of working time that participants interpret from English is M = 70% (SD = 18%). Twenty interpreters consider English their preferred relay language.[3] The mean number of working languages was M = 3.0 (SD = 1.0). When working languages were ordered from strongest to weakest, the mean ranking of English among participants was M = 1.4 (SD = 0.6), i.e. for most participants, English was their first, strongest working language.

2.3 Apparatus

All tasks (working memory and simultaneous interpreting) were presented on a portable computer HP Compaq nc8430, with a 15.4-inch screen (maximum resolution 1680x1050) and operating system Microsoft Windows XP Professional. Working memory tasks were programmed and presented as computer-controlled experiments using E-Prime 2.0 (Schneider, Eschman and Zuccolotto 2002). Responses to tasks were logged using a standard keyboard in E-Prime 2.0.

Simultaneous interpreting materials were recorded using a Sony HDV 1080i digital video camera. The recordings were then digitized, edited (picture and sound) using Microsoft Windows Movie Maker 5.1 software, and saved as.*avi* files (DVD quality video files). Participants' performance on the simultaneous interpreting tasks was recorded using an external microphone Philips SBC MD150 and Roland Edirol R-09 24 wave/mp3 recorder. Bandridge Soundstage 150 audio mixer was used to record the source text and interpreting as a dual-track recording.

2.4 Materials

2.4.1 *Cattell Culture Fair Test*

The paper-and pencil version of Cattell Culture Fair Test Scale 3 (Cattell and Catell, 1950), Part A, was used to establish participants' general cognitive abilities. The completion of the test was time-limited, the score was the number of correctly solved problems.

3. The EU environment is highly multilingual; up to 22 different languages are spoken in meetings. Where an interpreter does not work from one of the languages spoken on the floor, e.g. Hungarian, she uses relay interpretation, i.e. uses interpreting into a known language as the source for her own interpretation. Main relay languages are English, French and German.

© 2015. John Benjamins Publishing Company
All rights reserved

2.5 Working memory tasks

2.5.1 *Verbal span: letter span task*

Series of 5–9 letters (selection from the following consonants: B, C, D, G, K, P, Q, T; consonants with a monosyllabic name in Czech and Dutch) were presented in a fixed (randomly established) order, with each series length presented twice (5-5-8-7-8-6-7-6-9-9). Each series began with a fixation point in the centre of the screen displayed for 500ms, followed by a letter displayed for 1000ms and a blank screen for 500ms. At the end of the letter series, the English word "recall" prompted the participants to recall the series. Recall was written (pen and paper) and was limited to 15s. There were two practice trials (two series of five letters), and 10 experimental trials. Each series was scored as a proportion of correctly serially recalled letters within the series (Conway et al. 2005), the overall span was then calculated as the mean of all individual series scores. The task duration was approximately 4 minutes.

2.5.2 *Visuospatial span: Corsi task*

This task is a visuospatial variant of the verbal span. In a grid of nine irregularly distributed squares in a fixed configuration, individual squares were highlighted in sequences of varying length. Participants were asked to memorise a sequence of highlighted squares and recall them in the order of presentation. Sequences 3-9 squares long were presented in a fixed (randomly established) order, with each sequence length presented twice (3-6-5-4-6-8-5-9-4-3-8-7-7-9). Each sequence began with a static grid displayed for 1200ms, followed by the stimulus presentation (the same grid with one highlighted square) for 1000ms and a static grid between stimuli displayed for 500ms. At the end of the sequence, the English word "recall" prompted the participants to recall the sequence. A static grid was displayed again. Participants used a computer mouse to click on the previously highlighted squares in the same order in which they were presented or pressed a designated key to indicate a blank position. There were two practice trials (two sequences of three squares), and 14 experimental trials. Each sequence was scored as a proportion of correctly recalled squares within the sequence (Conway et al. 2005). The overall span was then calculated as the mean of all individual sequence scores. The task duration was approximately 5 minutes.

2.5.3 *Complex span*

Participants were asked to memorise a series of letters and recall them in the order of presentation. The letters were eight consonants (B, C, D, G, K, P, Q, T). Series of 5–8 letters were presented in a fixed (randomly established) order with each series length presented twice(5-7-6-6-7-8-5-8). Each series began with a fixation point

© 2015. John Benjamins Publishing Company
All rights reserved

in the centre of the screen displayed for 500ms, followed by a letter displayed for 1000ms. Each letter series was then followed by a processing task consisting of a parity judgement task on eight randomly selected digits (2–9), each constrained to appear maximum twice in one series. The digit appeared on screen for 1125ms and was followed by a delay of 375ms. At the end of the letter series, the English word "recall" appeared on the screen to prompt the participants to recall the letters. Recall was written (pen and paper) and limited to 15s.

There was a practice round. For the parity judgement task, participants were given five strings of eight digits each, with feedback. Practice on the parity judgement task was criterion based (80% accuracy rate). Then the whole task was practiced – two series of five letters, with no feedback. Each series was scored as a proportion of correctly recalled letters within the series (Conway et al. 2005). The span was then calculated as the mean of all individual series scores.

2.6 Simultaneous interpreting measures

2.6.1 *General considerations*

The simultaneous interpreting tasks were designed to be as realistic as possible. Interpreters were presented with three video recordings and asked to interpret the speeches. A number of pre-selected and manipulated variables were embedded in the input speeches. Three criteria were followed in the selection of variables: (1) theoretical interest for interpreting studies and some degree of intuitive justification why the measure should be related to working memory (e.g. relevant findings in general cognitive research or suggestions made by previous interpreting research), (2) empirical feasibility, i.e., the variable can be objectively measured, and (3) each variable covers a different aspect of the interpreting process. The variables were generally divided into those providing a measure of local or global processing. Local processes were measured at specific points (specific linguistic phenomena), while global processes were considered to span the whole task.

Local processing included measures of lexical, syntactic and semantic processing. *Lexical processing* was operationalised as the interpretation of figures (i.e. numbers, including amounts, percentages, dates, monetary values, etc.), a traditional salient feature, considered to be difficult due to their lack of semantic content. It is assumed that few other linguistic items require such reliance on memory in the context of interpreting. *Semantic processing* was operationalised as sentences containing double negation. Psycholinguistic research shows that a positive affirmative clause is neutral and unmarked. Engle and Conway (1998) concluded that such sentences do not recruit working memory. Negative affirmative clauses, on the other hand, are marked, hence more difficult (Clark 1969), and

© 2015. John Benjamins Publishing Company
All rights reserved

their comprehension requires more neural activation (Carpenter, Just and Reichle 2000), indicating that they are more cognitively demanding and recruit more resources, including working memory. In the context of interpreting, Büllow-Møller (1999) has shown that interpreters make more errors in marked sentences (negative, modal, etc.) than in unmarked sentences. Finally, *syntactic processing* was operationalised as interpretation of sentences with a complex syntactic structure. Specifically, Andrews et al. (2006) have shown that working memory is associated with more successful comprehension of sentences containing relative clauses, which require the integration of several nouns and verbs into the correct relations. This holds especially for object-extracted relative clauses (King and Just 1991). Given the added difficulty of simultaneous interpreting, in comparison with self-paced monolingual reading, we opted for the simpler option of subject-extracted relative clauses.

Global processing measures included: vocabulary richness, ear-voice span and performance under different speeds of delivery. *Vocabulary richness* is a measure of how varied one's vocabulary is and how large one's mental lexicon is. Larger working memory capacity has been associated with acquisition of new words (Baddeley et al. 1998), meaning inference and production (Daneman and Green 1986). In interpreting, Lamberger-Felber (2001) has shown there is a great variability in the use of vocabulary by interpreters. Vocabulary richness was operationalised into two measures: type/token ratio and unique vocabulary. Type/token ratio is a standard measure used in corpus linguistics. It compares the total number of words in the output (tokens), with the number of unique words used (types). Unique vocabulary was measured as the number of words used only by a given interpreter. *Ear-voice span* is required in interpreting to carefully balance the task and external constraints, such as the need to wait for a meaningful chunk of information on the one hand and processing the input fast enough as not to overload memory. Lee (2002) proposed a "watershed" value of EVS: time lags longer than approximately 4 seconds are associated with increased error rates. Again, ear-voice span is highly variable in interpreters (Lamberger-Felber 2001). Finally, *speed* of delivery was manipulated in order to measure how interpreters cope with the varying demands. By varying speed, interpreters are presented with a different amount of input in the same amount of time. At higher speeds, interpreters were shown to make more errors and omissions and increase their EVS (Gerver 1969/2002). By using this measure, we wish to explore how interpreters respond to input at different speeds and whether any differences in performance can be related to differences in working memory.

© 2015. John Benjamins Publishing Company
All rights reserved

2.6.2 *Text selection and manipulation*

Three texts were developed for the simultaneous interpreting tasks. Text 1 (Amnesty) was a genuine conference contribution available on the internet. The seminar, entitled "Business and Human Rights Seminar" took place in London in December 2005.[4] It was a high-level event with participants representing large corporations (such as BP, Gap), major international organisations (such as the United Nations or Amnesty International), and was the 3rd event in a series of seminars on ethical issues in international business. The contribution by a representative of Amnesty International was slightly shortened so as to be approximately 20 minutes long when delivered at a moderate pace. A total of 30 sentences in the text were manipulated to provide controlled material for the dependent variables. The sentences were of three types, containing (a) syntactically complex structure, (b) semantic complexity, and (c) numbers. All thirty sentences were embedded in the Amnesty text with the constraint that no two manipulated sentences can follow immediately one after another.

Ten sentences had a complex syntactical structure consisting of *subject + subject extracted relative clause 1 + subject-extracted relative clause 2 + main verb + verb complements*, as in *People who often eat fast food and who do not exercise run a higher risk of heart disease.*[5] The sentences were developed in English and then translated into the target languages Czech and Dutch to verify that both target languages have a theoretical linguistic capacity (a) to express the source text syntactic structure, and (b) to place similar production demand on the interpreter (measured in the number of words; the most important parameter was the distance in words separating the subject and main verb).

Ten sentences were manipulated to contain a complex semantic phenomenon consisting of a double negation. Five sentences contained the structure *verb + negation (not) + verb + negation (not)*, as in *We did not decide not to go*. Five sentences contained the structure *verb + negation (not) + negative verb*, as in *We did not disagree*. As in the case of syntactically complex sentences, the stimulus material was first produced in English, then translated into Czech and Dutch to verify linguistic viability of the material and the approximate production demands, measured in the number of words required to express the same idea in the target language (see Timarová 2012, for full details).

Finally, ten sentences were manipulated to contain two or three figures, as in *Over the last 15 years, the average turnover for our 251 branches has increased by*

4. http://business-humanrights.org

5. Actual stimuli are not listed to allow for use of the same materials in future studies. For a complete list of the stimulus materials, see Timarová (2012) or contact the authors.

© 2015. John Benjamins Publishing Company
All rights reserved

76%. The sentences were developed in English, translated into Czech and Dutch, and the target language versions compared for the overall sentence length (in words) and length of the embedded figures (in syllables).

Another text was selected from a background material to another contribution from the same event. It was a written country report on how companies in a given country comply with human rights. The text was significantly shortened so as to be approximately 5–6 minutes long when delivered at a moderate pace. The short version served as a basis for the development of two other texts, each being the said country report on a different country, Brazil and China (Texts 2 and 3). Each of the two texts contained an identical introduction and conclusion. The main body of the text included (a) a list of industry sectors surveyed in the report and the number of companies analysed in each sector, and (b) a list of various human rights and the number of companies which support the specific right. The lists were either presented as a list of items, or embedded in full sentences. Where the list was embedded, the text providing context was identical in the two texts, so that the only difference between the two texts was in the two lists. Lists for each text were then matched for length of the original delivery (English) and length of the translation into Czech and Dutch (see Timarová 2012 for full details). The lists of figures were matched in terms of syllables (figures do not evoke semantic concepts and were considered to tax memory in a more mechanistic way).

2.6.3 *Video and audio recordings*

All three texts, Amnesty, China and Brazil, were recorded by a native British English male speaker with a neutral accent. All speeches were written and read, with no attempts to oralise them, in order to make the stimulus material challenging even for the most experienced interpreters, and to avoid ceiling effects. The Amnesty text was recorded at 125 words per minute (wpm). The China text was delivered at a speed of 138 wpm, the Brazil text at 117 wpm, to provide a contrasting condition for the interpretation of embedded lists. Previous research suggests that ideal input speed for simultaneous interpreting is between 90 and 120wpm (Gerver 1969/2002), although speed determined purely in terms of words per minute is only one factor. Information density (spontaneous speech vs written text read out), semantic and syntactic simplicity vs complexity, pauses and their distribution, or intonation contribute to the speech being perceived as faster or slower (see Pöchhacker 2004, 129–130 for an overview).

In all recordings, the speaker was seated against a white background at a table, and his head and torso appeared in the picture. The recording allowed a good visual perception of the speaker's face and facial movements, including lip movements and hand gestures. Every effort was made to ensure maximum video and audio quality, although there were some natural limitations of the technology

© 2015. John Benjamins Publishing Company
All rights reserved

used. As a result, the quality of sound was inferior to the standards interpreters are used to in their professional environment, although not to the extent that it would seriously hamper their performance. Prior to testing, a sample of the recording was shown to and approved by three professional interpreters/researchers (none of whom participated in the study) to verify the recording quality and suitability for laboratory testing under environmental conditions simulating as closely as possible a real interpreting event.

2.7 Interpreting measures

2.7.1 *Syntactic processing*

The ten manipulated sentences containing a complex syntactic structure served as a measure of syntactic processing. For each sentence, interpretation was assessed as either preserving the subject-main verb agreement across the two intervening relative clauses, or not preserving the agreement. Accuracy and completeness of the rest of the sentence was not evaluated in any way. The maximum possible score was 10.

2.7.2 *Semantic processing*

Disambiguation of the double negation was assessed as either correct or incorrect. The disambiguation could have been achieved by similar grammatical means (using negation), or by an alternative way of expression. For example, the sentence *Some companies do not respect the rule not to employ children* was interpreted as *Some companies do not respect the ban on child labour.* The grammatical composition of the sentence is different, but the semantic complexity was correctly disambiguated. For each correctly disambiguated sentence, one point was awarded. The maximum possible score was 10.

2.7.3 *Lexical processing*

The ten manipulated sentences contained a total of 24 figures. Each figure was scored as either correct or incorrect. A figure was scored as correct if it had been interpreted with complete accuracy. Approximations or rounding were not accepted. The maximum possible score was 24.

2.7.4 *Vocabulary richness*

This analysis required a relative comparison between interpreters of lexical units in the target language. Therefore, only data from the 20 interpreters working into Czech were used. A segment of 374 words was selected from the middle of the Amnesty text. Using AntConc, corpus management software (Anthony 2011), individual word lists were compiled from interpreting transcriptions. Each word

© 2015. John Benjamins Publishing Company
All rights reserved

list was exported to Microsoft Excel and cleaned: all numbers and numerals were deleted, as were morphological forms (declensions and conjugations) of the same word (*do – did – done*), negative forms of verbs, comparative and superlative forms of adjectives, other than personal pronouns, and all slips of the tongue and unfinished words. Mispronounced words were restored to their correct form. The clean list contained all types (unique words) used by an interpreter. Individual vocabulary richness was then calculated using the standard measure of type/token ratio, i.e. the number of unique words divided by the total number of words.

2.7.5 *Unique vocabulary*

As a second measure, a personal unique vocabulary score was determined as the number of words used by one interpreter only. For this analysis, all individual word lists were compiled into one. For each interpreter, the number of words used only by that interpreter was counted.

2.7.6 *Ear-voice span (EVS)*

The distance the interpreter keeps from the speaker, or temporal delay between source text and target text, was measured at the beginning of the 30 manipulated sentences (Text Amnesty). The measurement was made on the basis of semantic correspondence. For example, a sentence in the target text may have been truncated (contain only some of the source text information) or it may have formally started, but contain a large gap, as in *And as mentioned before… (2s pause)… if a company does not respect the ban on child labour….* In such a case *and as mentioned before* may be a norm-induced filler ("keep talking"), which is not semantically motivated by the source text. The measurement would then be made on *if a company*. Sentences, which were omitted in their entirety, resulted in missing values. The distance between the two cue points (cue range length) was calculated by Adobe Audition (Adobe Systems Incorporated 2003). This resulted in a maximum of 30 individual values for each participant. Due to large variability in the length of the EVS, median EVS was calculated as a measure of the average time lag.

2.7.7 *Effect of speed delivery*

The effect of speed delivery was measured as the difference in the number of correctly interpreted items (companies-difference) between two matched texts, a fast text (China) and a slow text (Brazil). Each text contained a total of 72 items,[6] either as figures or as lists of industry sectors and various human rights. Each participant interpreted both texts in a fixed order (China, Brazil). The total of correctly interpreted items in each text was counted. Each item had to be interpreted fully

6. Some list items were repeated in the text.

© 2015. John Benjamins Publishing Company
All rights reserved

and accurately, approximations or partial interpretation were not accepted. For example, if *food and beverage industry* was interpreted as *food industry*, the item was assessed as incorrect. Similarly, *45.3%* interpreted as *45%, 45.4%* or *around 45%* were considered incorrect. The maximum possible score for each text was 72. Additionally, the average of correctly interpreted items in the two texts (companies-average) was taken as a measure of accuracy in conditions of high speed of delivery.

2.8 Procedure

Interpreters were recruited via personal contact or email by the researchers. Individual appointments were made with interpreters for the testing. All participants completed the tests in the same order. The testing location was determined by participants' availability: some participants were tested in their homes, others were tested in interpreting booths at their place of work. The order of tests was the letter span task, Corsi task and an interpreting task (text Amnesty). For the interpreting task, participants were given basic contextual information about the event (seminar programme), and shown a video recording of an introduction to the event (see Timarová 2012, for full details). Next, interpreters completed the complex span task, and did another interpreting task (texts China and Brazil).[7]

3. Results

Data were initially analysed and screened. Outliers were defined as values ±3SD from the mean; in the present dataset, no outliers were present and hence all data were retained for further analysis. Descriptive statistics for the working memory tests and interpreting measures are in Table 2. The table shows mean values and standard deviation, and the range of scores achieved. For working memory tests, reliability was calculated using the split-half (odd-even) method and Spearman-Brown coefficient. Reliability was generally good, with the exception of the Corsi task, which may be due to the low number of observations. For vocabulary measures, only data from the Czech interpreters were used, resulting in a smaller sample size.

A series of two-way ANOVAs was conducted to examine relationship of sex and mother tongue to age and working experience (both in years and days). All main effects of sex and mother tongue and all interactions were non-significant, indicating that there was no difference between men and women, and between

7. The procedure refers to tests relevant for the present report. The study was larger in scope and included further tests. See Timarová (2012) for further details of the complete study.

© 2015. John Benjamins Publishing Company
All rights reserved

Table 2. Descriptive statistics for working memory tasks and interpreting measures.

Measure	N	*M*	*SD*	Range	Reliability [a]
Letter span (proportion correct)	28	.63	.13	.40 to.92	.73
Corsi (proportion correct)	28	.70	.09	.52 to.85	.45
Complex span (proportion correct)	28	.62	.18	.17 to.90	.83
Cattell (total correct)	28	28.3	4.46	17 to 36	
Figures (number correct, max 24)	28	14.3	4.5	5 to 22	
Syntax (number correct, max 10)	28	6.1	1.9	3 to 10	
Negatives (number correct, max 10)	28	7.3	2.1	3 to 10	
Median ear-voice span (seconds)	28	3.2	.8	1.95 to 4.91	
Vocabulary richness (type/token ratio)	20	.55	.04	.46 to.60	
Unique vocabulary (number of words)	20	19.0	5.5	10 to 29	
Companies-difference (number of interpreted items)	26[b]	8.8	6.5	−3 to 22[c]	
Companies average (number of interpreted items, max 72)	26[b]	51.8	9.7	29 to 69.5	

[a] Reliability was calculated on working memory tasks only, using the Spearman-Brown coefficient and split-half (odd-even) method.

[b] Faulty recording resulted in loss of data for two participants

[c] If more items were interpreted on the fast text than on the slow text, this resulted in a negative score

Czech and Dutch speakers and sex and mother tongue will therefore not be considered as confounding variables in relation to participant characteristics. A series of independent samples t-tests were conducted to examine differences between males and females on their working memory functions. There were no differences between male and female interpreters, nor were there differences between males and females on any of the interpreting measures. As for mother tongue, there was a significant difference between Czech and Dutch interpreters on the average accuracy in the companies texts ($M_{\text{Czech}} = 49.47$, $SD_{\text{Czech}} = 9.45$, $M_{\text{Dutch}} = 57.93$, $SD_{\text{Dutch}} = 8.04$, $t(24) = -2.10$, $p = .047$) and a marginally significant difference on the difference in accuracy between the companies texts ($M_{\text{Czech}} = 10.11$,

© 2015. John Benjamins Publishing Company
All rights reserved

SD_{Czech} = 6.39, M_{Dutch} = 5.29, SD_{Dutch} = 5.62, $t(24) = 1.76$, $p = .09$). Dutch interpreters achieved higher accuracy in the interpretation of the companies texts, and were marginally significantly less affected by speed, than Czech interpreters. There were no other differences associated with the interpreters' mother tongue.

Correlation coefficients (Spearman) between participant characteristics, working memory and simultaneous interpreting are in Table 3. The main findings are the following: (1) Age and experience (both in years and days) are strongly related. (2) The measure of general cognitive ability (Cattell), as well as measures of working memory are negatively related to age and experience. (3) Among the measures of working memory, letter span is related to complex span. (4) Age and experience show several relationships to various measures of simultaneous interpreting. (5) Measures of working memory are generally unrelated to simultaneous interpreting measures, except some marginally significant relationships between the letter span and measures of lexical processing (figures, companies-average). Because of the very strong relationship between age and experience, these two variables are likely to confound the relationship to other measures. Additional analyses were performed where working memory and simultaneous interpreting measures were correlated with experience with the effect of age removed (partial Pearson correlation on ranked data; Iman and Conover 1979). The partial correlations are in Table 4 and show that relationships are generally weaker. These findings will now be discussed in turn.

Table 3. Correlation matrix (Spearman) of working memory tasks, simultaneous interpreting measures and participant characteristics.

	Age	Experience years	Experience days	Cattell	Letter	Corsi	Complex
Experience years	.83**						
Experience days	.70**	.89**					
Cattell	−.57**	−.58**	−.47**				
Letter span	−.26	−.20	−.22	.28			
Corsi	−.38**	−.30	−.25	.32	.13		
Complex span	−.34*	−.37*	−.38**	.36*	.69**	.15	
Syntax	.40**	.44**	.37*	−.23	.19	−.12	−.19
Figures	.08	.27	.24	−.14	.34*	−.18	.18
Negatives	.40**	.59**	.62**	−.20	.03	−.11	−.11
Vocabulary: Ratio	.35	.40*	.26	−.33	−.30	−.10	−.37
Vocabulary: Unique	.34	.43*	.27	−.29	−.18	−.37	−.28
Companies: Difference	−.38*	−.32	−.39*	.19	.11	−.07	.01
Companies: Average	.39*	.52**	.51**	−.05	.37*	−.22	.06
Median EVS	−.22	−.36	−.43**	.18	−.01	−.03	.07

** $p < .05$, * $.05 \le p < .10$

© 2015. John Benjamins Publishing Company
All rights reserved

Table 4. Partial correlations (Pearson on ranked data) controlling for age.

	Experience years	Experience days
Cattell	−.22	−.12
Letter span	.04	−.06
Corsi	.03	.02
Complex span	−.18	−.22
Syntax	.21	.15
Figures	.39**	.29
Negatives	.51**	.53**
Vocabulary: Ratio	.25	−.02
Vocabulary: Unique	.30	−.02
Companies: Difference	−.07	−.21
Companies: Average	.42**	.39*
Median EVS	−.33*	−.40**

**$p < .05$, *$.05 \le p < .10$

4. Discussion

4.1 Relationship between age, general cognitive ability and interpreting experience

The relationship between age and experience, especially when measured in years, is very strong and positive. This is not surprising: more experienced interpreters will tend to be older than less experienced interpreters. The very strong, but not perfect correlation between experience measured in years and experience measured in the number of days worked is a useful reminder that interpreters with the same experience in the number of years may differ on the number of days they worked. There is also a fairly strong negative relationship between the test of general cognitive ability (the Cattell test) and both age and interpreting experience, with the relationship being of the same direction and magnitude for all three variables. The most interesting of these is the negative relationship between the Cattell test and interpreting experience. The Cattell test score is based on the number of correctly solved abstract problems and therefore shows that more experienced interpreters perform worse (solve fewer abstract problems correctly) than less experienced interpreters, which would indicate that interpreters' general cognitive abilities decline with increased experience. Such a conclusion is highly counterintuitive and suggests that a closer examination of the relationship with age is necessary. The Cattell test and age are also negatively correlated, indicating that cognitive abilities decline with increased age, which is consistent with our knowledge of the general age-related development

© 2015. John Benjamins Publishing Company
All rights reserved

of human cognition. Taking these two results together, a plausible explanation is that the negative relationship between the Cattell test and interpreting experience reflects a hidden effect of age. When this effect is statistically removed (Table 4), the relationship between interpreting experience and the Cattell test is reduced, although it remains weakly negative.

Age thus emerges as a strong confounding variable and needs to be carefully considered in further analyses.[8] Our basic interpretation of the implications is that in this case, our interest lies in relating cognitive functions (working memory) to skilled behaviour (simultaneous interpreting). Cognitive functions are associated with decline due to age, while skilled behaviour would be expected to improve with more experience. Since more experience implies increased age, the two tendencies – decline in cognitive functioning and improvement in skilled performance – may in fact act against each other. The present sample included participants in the age range 25 to 55 years. No data are available on age-related changes in interpreting which would provide guidance on interpreting the results. The upper age values in the present sample fall outside the scope of general literature on cognitive ageing but we cannot exclude the possibility that some age-related changes may take place in relation to performing simultaneous interpreting even in the present age group, and to the extent possible, age will be considered in all other analyses. For a study specifically addressing age effects in interpreters and control participants, see Signorelli et al. (2012).

4.2 Relationship between working memory, cognitive ability, age and interpreting experience

Let us first consider the relationship between the three working memory tasks. The letter span task and the complex span task are positively related. Both the letter span and the complex span measure the ability to store and recall presented stimuli, with the difference that the letter span task is a simple storage task, while the complex span task contains a processing task and is thus considered a better measure of working memory. The positive relationship can thus be interpreted as reflecting the common component of both tasks, the storage function of working memory. The letter span task and the complex span task are unrelated to the

8. This does not necessarily mean that older interpreters in our sample are cognitively "old", only that there is a general trend of cognitive patterns in relation to age. Even if older participants had scores lower by one point only, or took 1ms longer to respond, this would show as a statistically significant relationship, if sufficiently consistent. In any case, the age range of the present sample is 25–55 years, which is certainly not an age group where significant deterioration of cognitive functions known as ageing occurs.

© 2015. John Benjamins Publishing Company
All rights reserved

Corsi task, which is in line with general literature (Baddeley 2000) distinguishing between verbal and visuospatial memory. All three tasks are weakly positively correlated with the Cattell test. The complex span task shows the strongest relationship, which is again in line with general literature (Conway et al. 2005), which indicates that complex working memory tasks are more strongly related to measures of general cognitive ability than simple storage tasks. In this respect, our sample of interpreters does not seem to deviate in any way from generally applicable patterns of the structure of working memory.

Moving on to the relationship between measures of working memory on the one hand and age and interpreting experience on the other hand, we note again that there is a strong pattern. Relationships between working memory measures and interpreting experience mirror those between working memory measures and age. Relationships with age are stronger than those with interpreting experience and all relationships are negative, meaning that higher age is generally associated with worse performance on the working memory tasks. This is again consistent with deterioration of cognitive functions with increased age. The three span tasks, the letter span, the Corsi task and the complex span task, all show negative relationships with interpreting experience. This pattern is similar to the pattern seen in the first column of Table 3, which shows correlations with age. In other words, with increased experience, the performance on the span tasks decreases. Once the relationship with age is removed (Table 4), the relationship is largely reduced. This particular finding is very interesting and important. As discussed in the introductory review of previous research, most of the empirical studies set out to test a hypothesis of interpreters' superior working memory in comparison to non-interpreters. While this is not the primary question in this study, the present data can be evaluated from the perspective of the superiority hypothesis as well. Padilla et al. (1995) formulated the hypothesis in terms of enlargement of working memory capacity through training and practice, predicting that experienced interpreters will demonstrate larger working memory capacity than interpreting students and non-interpreters. Our data do not support this view. If working memory capacity were to be enlarged with practice, we would expect to see a positive correlation between experience and the span tasks: more experience associated with better performance on the working memory tests. However, our data show absence of such a relationship, and perhaps a very slight trend towards a decrease in working memory capacity, as seen in the weak negative correlation between interpreting experience and the complex span task. It is important to point out that neither do our data disqualify the hypothesis. First, no control group is included in the present study, and it is possible that those who become interpreters enter the training with a larger-than-normal working memory capacity and retain it. In such a case, interpreters would still demonstrate superior working memory

© 2015. John Benjamins Publishing Company
All rights reserved

to non-interpreters, a comparison we cannot make. Secondly, working memory capacity may be enlarged through training, as Padilla et al. (1995) suggested, but this change could be constrained in time (perhaps take place rapidly during training), after which working memory capacity would level off and stay constant. A third possibility is that there is a general decline of working memory capacity in normal population, but that due to interpreters' intensive use of working memory, the decline is slower than in non-interpreters, and demonstrated here by the non-significant trends. The superiority hypothesis is empirically contentious, and the indirect evidence presented here is but one small piece in the puzzle. Nevertheless, the conclusion on the basis of our data is that working memory capacity does not seem to change with interpreting practice, and whatever role it plays in interpreting, the effect would be attributed to innate abilities rather than improvement with practice.

4.3 Relationship between simultaneous interpreting, age and experience

The bottom half of Table 3 shows correlations between simultaneous interpreting measures and other variables. With regard to age, experience and general cognitive ability, we note that the pattern is different from what we have seen in relation to working memory. There, age was the more strongly related variable, with experience correlating more weakly and less often significantly. In the simultaneous interpreting tasks, on the other hand, experience is the variable which correlates more strongly, and age usually produced correlations in the same direction, but often weaker. Table 4 shows that after age has been statistically removed, the relationship between interpreting experience and measures of simultaneous interpreting changes, although not in a uniform pattern. It is also interesting that correlations with Cattell, the test of general cognitive ability, are often negative, which would suggest that interpreters with higher general cognitive ability do worse on interpreting tasks than interpreters with lower general cognitive ability. That is again counterintuitive, and an obvious suggestion is that this is again a hidden effect of age. A supplementary analysis (not shown here due to space constraints) indicates that once age is controlled for, the relationships between the Cattell test and measures of interpreting experience are either weakly positive or close to zero. The interplay of age and simultaneous interpreting, together with unexpected relationships with general cognitive abilities, is highly complex. It seems that there are two counteracting tendencies. The present data were not collected with these issues as a specific area of interest and more detailed analyses cannot be pursued here. We note, however, that more focused research is needed to address the question of participant characteristics, and more specifically age and general cognitive abilities, and their interaction with experience and interpreting skills.

© 2015. John Benjamins Publishing Company
All rights reserved

4.4 Relationship between working memory and simultaneous interpreting

Finally, let us look at the relationship between working memory and measures of simultaneous interpreting. The broadest conclusion is that there is a general lack of a relationship between the two constructs. The letter span, a measure of verbal short-term memory without a processing component, shows a relationship with simultaneous interpreting, but the relationship only approaches significance. The Corsi task, a measure of visuospatial memory, and the complex span task, a variant of complex working memory tasks of the reading span type, do not seem to be related to any of the measures of interpreting selected for this study. The letter span task, too, is related only weakly and statistically marginally significantly to two measures of simultaneous interpreting: the number of correctly interpreted figures and the average number of correctly interpreted items in the companies texts. In both cases, the interpreting task consists of horizontal translation (Seleskovitch 1968/1978), a process further enhanced in the present data by the selected scoring method, which only accepted exact matches as correct interpretations. The verbatim memory demands of the letter span task provide a plausible explanation for the observed relationship, and also an explanation of why no such relationship is present between, for example, letter span and negatives, where the interpreting task requires analytical processing, rather than simple storage and transcoding. To provide a more complete picture, the same analysis (correlations between working memory and simultaneous interpreting measures) was run while controlling for the effects of age, which turned out to be a nuisance variable in the analysis of the structure of simultaneous interpreting. The essential picture does not change and the full matrix is not reproduced here as it does not add much new information. The complex span task, a variant of the tests most often employed in previous research, shows correlations very close to zero or weakly negative, which goes against predictions of close relationship between working memory and interpreting skills.

One possible explanation for the lack of relationship could be that interpreters are too homogenous and at the top of working memory capacity range, i.e., that there is a ceiling effect. In our opinion, closer examination of the data speaks against both homogeneity and a ceiling effect. The means, standard deviations and ranges seem to indicate sufficient variability in the data, as do correlations of the participant characteristics and working memory on the one hand and of participant characteristics and interpreting measures on the other. The patterns in these correlations are just what we would expect. This however does not exclude the possibility that interpreters' working memory capacity is larger than that of non-interpreters. Previous research shows that interpreters score high on working memory capacity tasks, although they do not always perform significantly better than controls (for an overview see Köpke and Signorelli 2012). Large

© 2015. John Benjamins Publishing Company
All rights reserved

working memory capacity may be a basic necessity for successfully acquiring and/or performing the interpreting skill. In the context of the present study, however, individual differences in performance on interpreting tasks (i.e. on measures of specific types of processing) were not associated with differences on working memory capacity measures. The question remains how exactly interpreters use working memory capacity during interpreting. A more fruitful line of research currently focuses on exploring the role of non-storage components of working memory. Padilla et al. (2005) argued for better use of memory resources, rather than differences in storage capacity, and executive functions have been recently linked to interpreters' quality ratings (Macnamara et al. 2011) and to several specific measures of the interpreters‘ performance (Timarová et al. 2013).

5. Conclusion

Working memory capacity was previously shown to be related to interpreting performance in less skilled groups (interpreting students, untrained bilinguals), but the results of the present study generally do not support the idea of extensive working memory capacity involvement in simultaneous interpreting performed by professional interpreters. The limited involvement found in this study concerns only very specific, albeit important, types of processing, which represent a fraction of the processes involved. There are some important methodological differences between previous research and the present study, which may potentially skew the results. The most important differences are the selection of interpreting variables, where previous studies typically measured interpreting using more holistic scores such as accuracy of sentences, and participant variables, chief among them age effects. Studies conducted with student populations are probably much more homogenous in terms of age and would not be expected to be affected by this variable to the same extent as a sample of professional interpreters with age range spanning several decades. Nevertheless, the lack of relationships between working memory capacity measures and experience on the one hand, and specific measures of simultaneous interpreting performance on the other, lead us to support Köpke and Signorelli's (2012) conclusion that processes tapping the storage component of working memory do not seem to play a crucial role in professionals with a higher degree of skill acquisition.

© 2015. John Benjamins Publishing Company
All rights reserved

References

Ackerman, Phillip L. 1988. "Determinants of Individual Differences during Skill Acquisition: Cognitive Abilities and Information Processing." *Journal of Experimental Psychology: General* 117 (3): 288–318. DOI: 10.1037/0096-3445.117.3.288

Adobe Systems Incorporated. 2003. *Adobe Audition* (Version 1.0) [Computer software] Available from www.adobe.com.

Andrews, Glenda, Damian Birney, and Graeme S. Halford. 2006. "Relational Processing and Working Memory Capacity in Comprehension of relative Clause Sentences." *Memory and Cognition* 34 (6): 1325–1340. DOI: 10.3758/BF03193275

Anthony, Laurence. 2011. *AntConc (Version 3.2.4)* [Computer Software]. Tokyo, Japan: Waseda University. Available from http://www.antlab.sci.waseda.ac.jp/

Baddeley, Alan. 2000. "The Episodic Buffer: A New Component of Working Memory?" *Trends in Cognitive Sciences* 4 (11): 417–423. DOI: 10.1016/S1364-6613(00)01538-2

Baddeley, Alan, Susan Gathercole, and Constanza Papagno. 1998. "The Phonological Loop as a Language Learning Device." *Psychological Review* 105 (1): 158–173. DOI: 10.1037/0033-295X.105.1.158

Baddeley, Alan D., and Graham J. Hitch. 1974. "Working Memory." In *The Psychology of Learning and Motivation: Advances in Research and Theory*, Vol. 8, ed. by G. Bower, 47–89. New York: Academic Press. DOI: 10.1016/S0079-7421(08)60452-1

Bajo, María Teresa, Francisca Padilla, and Presentación Padilla. 2000. "Comprehension Processes in Simultaneous Interpreting." In *Translation in Context*, ed. by Andrew Chesterman, Natividad Gallardo San Salvador, and Yves Gambier, 127–142. Amsterdam: John Benjamins. DOI: 10.1075/btl.39.15baj

Büllow-Møller, Anne Marie. 1999. "Existential Problems: On the Processing of Irrealis in Simultaneous Interpreting." *Interpreting* 4 (2): 145–168. DOI: 10.1075/intp.4.2.02bue

Carpenter, Patricia A., Marcel A. Just, and Erik D. Reichle. 2000. "Working Memory and Executive Function: Evidence from Neuroimaging." *Current Opinion in Neurobiology* 10: 195–199. DOI: 10.1016/S0959-4388(00)00074-X

Cattell, Raymond B., and Alberta Karen S. Cattell. 1950. *Test of g: Culture Free*. Champaign, IL: Institute for personality and ability testing.

Chincotta, Dino, and Geoffrey Underwood. 1998. "Simultaneous Interpreters and the Effect of Concurrent Articulation on Immediate Memory. A Bilingual Digit Span Study." *Interpreting* 3 (1): 1–20. DOI: 10.1075/intp.3.1.01chi

Christoffels, Ingrid K. 2004. *Cognitive Studies in Simultaneous Interpreting*. Ipskamp/Enschede: PrintPartners.

Christoffels, Ingrid K., Annette M. B. de Groot, and Judith F. Kroll. 2006. "Memory and Language Skills in Simultaneous Interpreters: The Role of Expertise and Language Proficiency." *Journal of Memory and Language* 54 (3): 324–345. DOI: 10.1016/j.jml.2005.12.004.

Clark, Herbert H. 1969. "Linguistic Processes in Deductive Reasoning." *Psychological Review* 76: 387–404. DOI: 10.1037/h0027578

Conway, Andrew R. A., Michael J. Kane, Michael F. Bunting, Zack Hambrick, Oliver Wilhelm, and Randall W. Engle. 2005. "Working Memory Span Tasks: A Methodological Review and a User's Guide." *Psychonomic Bulletin and Review* 12 (5): 769–786. DOI: 10.3758/BF03196772

© 2015. John Benjamins Publishing Company
All rights reserved

Cowan, Nelson. 1988. "Evolving Conceptions of Memory Storage, Selective Attention, and their Mutual Constraints within the Human Information-Processing System." *Psychological Bulletin* 104 (2): 163–191. DOI: 10.1037/0033-2909.104.2.163

Daneman, Meredyth, and Patricia A. Carpenter. 1980. "Individual Differences in Working Memory and Reading." *Journal of Verbal Learning and Verbal Behavior* 19: 450–466. DOI: 10.1016/S0022-5371(80)90312-6

Daneman, Meredyth, and Ian Green. 1986. "Individual Differences in Comprehending and Producing Words in Context." *Journal of Memory and Language* 25: 1–18. DOI: 10.1016/0749-596X(86)90018-5

Darò, Valeria. 1989. "The Role of Memory and Attention in Simultaneous Interpretation: A Neurolinguistic Approach." *The Interpreters' Newsletter* 2: 50–56.

Darò, Valeria, and Franco Fabbro. 1994. "Verbal Memory during Simultaneous Interpretation: Effects of Phonological Interference." *Applied Linguistics* 15 (4): 365–381. DOI: 10.1093/applin/15.4.365

Engle, Randall W., and Andrew R. A. Conway. 1998. "Working Memory and Comprehension." In *Working Memory and Thinking*, ed. by R. H. Logie, and K. J. Gilhooly, 67–91. Hove: Psychology Press.

Engle, Randall W., Stephen W. Tuholski, James E. Laughlin, and Andrew R. A. Conway. 1999. "Working Memory, Short-term Memory, and General Fulid Intelligence: A Latent-variable Approach." *Journal of Experimental Psychology: General* 128 (3): 309–331. DOI: 10.1037/0096-3445.128.3.309

Ericsson, K. Anders, and Walter Kintsch. 1995. "Long-term Working Memory." *Psychological Review* 102 (2): 211–245. DOI: 10.1037/0033-295X.102.2.211

Gerver, David. 1969/2002. "The Effects of Source Language Presentation Rate on the Performance of Simultaneous Conference Interpreters." In *The Interpreting Studies Reader*, ed. by F. Pöchhacker, and M. Shlesinger, 52–66. London and New York: Routledge.

Gerver, David. 1975. "A Psychological Approach to Simultaneous Interpreting." *Meta* 20 (2): 119–128. DOI: 10.7202/002885ar

Hermans, Daan, Rick van Dijk, and Ingrid K. Christoffels. 2007. *De effectiviteit van gebarentaaltolken in de communicatie tussen dove en horende mensen* [Effectiveness of sign language interpreting in communication between deaf and hearing people]. Unpublished final project report. Utrecht University of Applied Sciences, the Netherlands.

Hodáková, Soňa. 2009. *Pamäť v simultánnom a konzekutívnom tlmočení* [Memory in simultaneous and consecutive interpreting]. Unpublished PhD dissertation. Konštantín Filozof University, Nitra.

Iman, Ronald L., and W. J. Conover. 1979. "The use of the Rank Transform in Regression." *Technometrics* 21 (4): 499–509. DOI: 10.1080/00401706.1979.10489820

King, Jonathan, and Marcel A. Just. 1991. "Individual Differences in Syntactic Processing: The Role of Working Memory." *Journal of Memory and Language* 30: 580–602. DOI: 10.1016/0749-596X(91)90027-H

Köpke, Barbara, and Jean-Luc Nespoulous. 2006. "Working Memory Performance in Expert and Novice Interpreters." *Interpreting* 8 (1): 1–23. DOI: 10.1075/intp.8.1.02kop

Köpke, Barbara, and Teresa M. Signorelli. 2012. "Methodological Aspects of Working Memory Assessment in Simultaneous Interpreters." *International Journal of Bilingualism* 16 (2): 183–197. DOI: 10.1177/1367006911402981.

© 2015. John Benjamins Publishing Company
All rights reserved

Lamberger-Felber, Heike. 2001. "Text-oriented Research into Interpreting: Examples from a Case-study." *Hermes* 26: 39–63.

Lee, Tae-Hyung. 2002. "Ear-voice Span in English into Korean Simultaneous Interpretation." *Meta* 47 (4): 596–606. DOI: 10.7202/008039ar

Liu, Minhua. 2001. *Expertise in Simultaneous Interpreting: A Working Memory Analysis*. Unpublished doctoral dissertation, the University of Texas at Austin.

Liu, Minhua, Diane L. Schallert, and Patrick J. Carroll. 2004. "Working Memory and Expertise in Simultaneous Interpreting." *Interpreting* 6 (1): 19–42. DOI: 10.1075/intp.6.1.04liu.

Macnamara, Brooke N., Adam B. Moore, Judy A. Kegl, and Andrew R. A. Conway. 2011. "Domain-general Cognitive Abilities and Simultaneous Interpreting Skill." *Interpreting* 13 (1): 121–142. DOI: 10.1075/intp.13.1.08mac

Mizuno, Akira. 2005. "Process Model for Simultaneous Interpreting and Working Memory." *Meta* 50 (2): 739–752. DOI: 10.7202/011015ar

Nordet, Lilan, and Lara Voegtlin. 1998. *Les tests d'aptitude pour l'interprétation de conférence. La mémoire*[Aptitude testing for conference interpreting. Memory]. Unpublished master thesis. ETI, University of Geneva.

Padilla, Presentación, María T. Bajo, José J. Cañas, and Francisca Padilla. 1995. "Cognitive Processes of Memory in Simultaneous Interpretation." In *Topics in Interpreting Research*, ed. by Jorma Tommola, 61–71. Turku: University of Turku Press.

Padilla, Francisca, María T. Bajo, and Pedro Macizo. 2005. "Articulatory Suppression in Language Interpretation: Working Memory Capacity, Dual Tasking and Word Knowledge." *Bilingualism: Language and Cognition* 8 (3): 207–219. DOI: 10.1017/S1366728905002269

Pöchhacker, Franz. 2004. *Introducing Interpreting Studies*. London and New York: Routledge.

Schneider, Walter, Amy Eschman, and Anthony Zuccolotto. 2002. *E-Prime User's Guide*. Pittsburgh: Psychology Software Tools Inc.

Seleskovitch, D. 1968/1978. *English. Interpreting for International Conferences. Problems of Language and Communication*. Washington: Pen and Booth.

Shlesinger, Miriam. 2000. *Strategic Allocation of Working Memory and Other Attentional Resources in Simultaneous Interpreting*. Unpublished PhD dissertation, Bar Ilan University, Ramat Gan, Israel.

Signorelli, Teresa M., Henk J. Haarmann, and Loraine K. Obler. 2012. "Working Memory in Simultaneous Interpreters: Effects of Task and Age." *International Journal of Bilingualism* 16 (2): 198–212. DOI: 10.1177/1367006911403200.

Timarová, Šárka. 2007. *Measuring Working Memory in Interpreters*. Unpublished DEA thesis, ETI, University of Geneva.

Timarová, Šárka. 2008. "Working Memory and Simultaneous Interpreting." In *Translation and Its Others: Selected Papers of the CETRA Research Seminar in Translation Studies 2007*, ed. by Pieter Boulogne. http://www.arts.kuleuven.be/cetra/papers.

Timarová, Šárka. 2012. *Working Memory in Conference Simultaneous Interpreting*. Unpublished PhD dissertation, Charles University in Prague/University of Leuven.

Tzou, Yeh-Zu, Zohreh R. Eslami, Hsin-Chin Chen, and Jyotsna Vaid. 2012. "Effects of Language Proficiency and Degree of Formal Training in Simultaneous Interpreting on Working Memory and Interpreting Performance: Evidence from Mandarin-English Speakers." *International Journal of Bilingualism* 16 (2): 213–227. DOI: 10.1177/1367006911403197.

© 2015. John Benjamins Publishing Company
All rights reserved