Is it all in the mind? Investigating the presumed cognitive advantage of aspiring interpreters

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Abstract

In complex tasks such as interpreting, the importance of a well-functioning working memory can hardly be overestimated. However, as empirical studies have failed to produce consistent results with regard to the interpreter advantage in memory storage, recent studies tend to focus on executive control rather than storage capacity. To our knowledge, no such study has compared the possible cognitive advantage of aspiring interpreters relative to other multilinguals before training takes place, in spite of the fact that many interpreter selection procedures seek candidates with superior working memory skills. To this end, we have compared a group of 20 student interpreters with two other groups of advanced language users who were all at the start of their Master's training. Data were collected on three executive control functions: inhibition (resistance to interference and resistance to automatic response), shifting and updating. These functions were gauged by computer-based tasks, viz. an Attention Network Test, a Simon task, a Colour-Shape Switch task and a 2-back task. One storage capacity measure – a digit span task – was also included. Results revealed only negligible differences between the three groups at onset of training. The presumed cognitive advantage of aspiring interpreters with regard to executive control was not found.

Keywords: working memory, executive control, updating, inhibiting, switching

1. Introduction

In interpreting research, working memory has long been recognized as one of the most important cognitive aspects of simultaneous interpreting (Keiser 1965; Alexieva 1993; Darò 1995; Gile 1995, 1999). When we talk about working memory we refer to the brain system that is responsible for temporarily holding and manipulating small amounts of information. This brain system has been shown to play a crucial role in performing complex tasks such as language learning and language processing (Baddeley 1992, 2003). The four subsystem model of working memory (Baddeley & Hitch 1974; Baddeley, 2000, 2003) remains the most influential visualization of working memory to date: (1) the phonological loop, which is concerned with verbal and acoustic information, consists of a storage system and a subvocal rehearsal system, (2) the visuospatial sketchpad is its visual counterpart, (3) both are dependent on a higher-level control system, the central executive, which regulates the attentional control of working memory, (4) the episodic buffer is a multi-dimensional storage system combining both visual and verbal information that heavily depends on the central executive and allows for the storage of information that exceeds the capacity of the phonological loop or the visuospatial sketchpad.

Up to now, most empirical interpreter studies have focused on the phonological loop or on storage capacity, which is commonly measured using either a simple storage task, such as a forward digit span, or a more complex storage task, such as a reading or listening span task (e.g. Christoffels, de Groot & Kroll 2006; Liu, Schallert & Carroll 2004). These studies tend to compare interpreters with non-interpreters, hypothesizing that the interpreters will exhibit higher storage capacity. However, not all studies have been able to establish an interpreter advantage. Köpke and Signorelli (2012) attributed this variance to methodological differences between the studies. The studies that found higher storage capacity for interpreters mostly used free recall tasks (i.e. a task in which you can recall the words or digits in no particular order) (Padilla Benítez 1995; Padilla, Bajo & Macizo 2005; Köpke & Nespoulous 2006) whereas the studies that did not find a storage capacity advantage for the interpreter group seem to have used serial recall tasks (i.e. a task in which you need to recall the words or digits in the exact same order as they were given) (Christoffels et al. 2006; Köpke & Nespoulous 2006; Liu et al. 2004; Padilla Benítez 1995). These studies will be discussed in greater detail in section two of this article. The mixed research outcomes might indicate that it is not storage capacity in itself that determines successful performance of complex tasks but rather how this storage is utilized. This places the role of the central executive or attentional-controlling system on the foreground, as serial ordering of item information taxes the executive function. Consequently, research has started to focus on these central executive functions (e.g. Köpke & Nespoulous 2006; Timarová et al. 2014; Morales, Padilla, Gómez-Ariza & Bajo 2015), as the possible locus of any working memory advantage for interpreters.

Empirical research into working memory capacity or executive control has rarely focussed on students prior to interpreter training and this is regarded a void in the field (Obler 2012). The current study aims to fill this void by focussing on the differences in working memory and executive control between three groups of advanced language learners in order to establish whether these differences can be attested prior to interpreter training. The language learners in this study have all completed a Bachelor’s degree in applied language studies before embarking on a Master’s degree in interpreting, translation or multilingual communication. Interpreting and translation are Master’s programmes with a long-standing tradition in Belgium. However, the Master’s in multilingual communication is a new programme that was designed to cater for the relatively large group of Bachelors in applied language studies that wish to pursue language careers apart from translation or interpreting. With this study we aim to establish whether students who opt for the interpreting programme already have better developed cognitive skills than their peers who choose to become translators or multilingual communication specialists.

We examined three executive functions – updating, inhibition (resistance to interference and resistance to automatic response) and shifting – (as described in Miyake et al. 2000), which were tested using computer-based response tasks which are considered to be domain-general. These executive functions are generally acknowledged in working memory theory (Baddeley 1996; Miyake & Friedman 1998) and have been selected on the basis of their relevance for the interpreting process. The updating function requires participants to compare new incoming information to information already held in the memory. This function is related to the interpreting task since interpreting involves handling a continuous stream of incoming speech while previous input is still being processed. The updating function was tested by means of a 2-back task, where participants had to decide whether the current stimulus, in the form of line drawings, was the same as the stimulus two trials before. Next, two types of inhibition were gauged. The Attention Network Test (ANT; Fan, McCandliss, Sommer, Raz & Posner 2002) evaluated participants’ inhibitory functions, as it requires them to ignore irrelevant stimuli and focus on the task at hand. As Timarová et al. (2014) noted, interpreters need to be able to ignore distractors such as the sound of their own voice and other sounds or visual disturbances during their performance. The second type of inhibitory control was tested by means of a Simon task (Simon & Rudell 1967), which measured the resistance to automatic response. For the interpreter this could translate into the resistance to use false cognates or to maintain the source language’s sentence structure. The fourth executive function under investigation is the shifting function. This is relevant in interpreting because of the continual shift between processing incoming language and producing oral translations. In addition to the executive control measures, we administered a digit span task to gauge students' storage capacity. The forward recall task is typically regarded as a measure of storage capacity, while the backward recall task also involves executive functions as the transformation of the digit sequence requires attention control (St Clair-Thompson & Allen 2013). This measure enabled us to verify whether there is a relation between storage capacity on the one hand and the executive functions on the other. The tasks employed are discussed in greater detail in section three of this paper. First, we present an overview of the relevant literature on working memory research. This review includes research on working memory storage and executive control in bilinguals, translators and interpreters. The main focus is, however, on interpreting studies, and more specifically on studies comparing interpreters to non-interpreters.

2. Literature review

Working memory and executive control in bilinguals

Language-related research into working memory and executive control has been rather prevalent in studies on bilinguals. This seems to dovetail with the importance that has been attributed to working memory in the execution of language tasks (Daneman & Carpenter 1980). A review of the recent literature seems to suggest that being a bilingual has a positive influence on one's cognitive abilities, especially in terms of executive control. Bilinguals are known to have both of their languages active at all times (Van Assche, Duyck & Hartsuiker 2012) which demands thorough cognitive control in order to use them effectively. As bilinguals appear to suffer few language intrusions or make few errors when they are required to switch from one language to the other, an efficient cognitive control mechanism seems to be in place (Woumans, Ceuleers, Van der Linden, Szmalec & Duyck 2015). A number of studies have suggested that this language control training transfers to general cognitive control, resulting in a cognitive control advantage for bilinguals beyond the linguistic domain. These studies find that bilinguals often outperform their monolingual peers on executive tasks measuring different aspects of control (e.g. Bialystok, Craik, Klein & Viswanathan 2004; Luk, De Sa & Bialystok 2011). The advantage that these bilinguals display on these tasks is two-fold. Some studies have disclosed a general processing advantage, with faster reaction times on trials that do not elicit any conflict (i.e. 'congruent trials') (e.g. Bialystok 2006; Costa, Hernández & Sebastián-Gallés 2008; Martin-Rhee & Bialystok 2008). Others have demonstrated superior conflict resolution skills in bilinguals, revealing smaller congruency effects (e.g. Bialystok, Craik & Ryan 2006; Costa, Hernández, Costa- Faidella & Sebastián-Gallés 2009). These effects are measured by calculating the difference in reaction times on congruent and incongruent trials. For instance, in the Simon task this would mean subtracting reaction times on all trials where position and colour of the dot elicit the same response from those on all trials where position and colour elicit a different response, thus creating the so-called *Simon effect*.

Interestingly, different attributes ascribed to specific types of bilingualism interact with the bilingual cognitive advantage. For instance, language switching frequency in daily life has been found to interact with the advantage, with frequent switchers performing better on cognitive control tasks (Verreyt, Woumans, Vandelanotte, Szmalec & Duyck 2015).

Working memory and executive control in translators

Within the field of translation studies, working memory research has focussed on interpreters rather than translators. Only a handful of studies focus on translators' working memory capacity. Rothe-Neves (2003) investigated the influence of working memory on the translation performance in an attempt to unravel the cognitive processes during translation tasks. He used verbal tasks adapted from Salthouse and Babcock's (1991) BAMT-UFMG test battery to compare processing speed, coordination and storage capacity between novice translators and professional translators. No differences between the working memory measures of the two groups were found. It has to be noted that only 6 students and 6 professionals took part in this study and that the average age difference between both groups was slightly more than 10 years. As working memory deteriorates with age (Park et al. 2002), but increases with experience (Klingberg 2009), it is difficult to dissociate the factor age or experience in this limited participant group. Another study on working memory and translation, albeit not in a professional translator context but rather on translation as a general bilingual test, examines the role of working memory in error-making. In this study Michael, Tokowicz, Degani and Smith (2011) investigated whether working memory and the ability to ignore task-irrelevant information – i.e. inhibition – is related to the ability to solve translation ambiguity, which occurs when a word has multiple translations. This translation ambiguity was investigated at word level during an oral single-word translation task with a time restriction of four seconds. In a population of 19 students, the best translation tasks could be ascribed to those students who obtained the highest scores on the working memory and the inhibition tests. Participants with low scores on the inhibition task made more errors in the translation task, even when they obtained high scores in the storage capacity task. The absence of a significant correlation between working memory capacity and the ability to inhibit seems to imply that relatively independent subsystems of working memory are at play and that having a large storage capacity does not necessarily transfer to possessing superior executive functions.

Working memory and executive control in interpreters

Empirical studies on working memory in interpreting have typically used span tasks to measure working memory capacity. To our knowledge, no study has yet compared the working memory functions of translators to those of interpreters, while that last group is often presumed to have a superior working memory because of the highly complex nature of the interpreting process. There are a number of studies using either simple or complex span tasks that have found that professional interpreters outperform non-interpreters and novice interpreters. For example, Christoffels et al. (2006) compared the working memory capacity of 13 trained interpreters with that of 40 bilingual university students and 15 highly proficient English teachers. The interpreters outperformed the students and the English teachers on their memory capacity as measured by a reading span task, a speaking span task and a word span task.

Scores on reading span tasks also differed significantly between interpreters and non-interpreters in studies by Signorelli (2008) and Tzou et al. (2012). In the former study, the same stimuli from the Christoffels et al.'s (2006) study were used in a group of 19 interpreters and 19 bilingual non-interpreters. The results revealed a significant effect of profession as the interpreters outperformed the bilingual control group. Much alike, Tzou et al. (2012) looked into the working memory capacity of 11 first-year student interpreters, 9 second-year students and 16 untrained bilingual controls. Both student groups outperformed the control group in a reading span task. In addition, the authors established a positive correlation between high memory span and simultaneous interpreting performance, regardless of training experience.

Next to studies that have attested a working memory advantage for interpreters, a number of studies have come to the opposite conclusion. Chincotta and Underwood (1998) did not find a working memory advantage in a digit span task with articulatory suppression in a population of 12 student interpreters and 12 bilingual controls. This task consisted of uttering a nonsense word while recalling sequences of digits. Köpke and Nespoulous (2006) also failed to attest a working memory advantage for professional interpreters in a listening span task and a recall task with articulatory suppression. In the recall task with articulatory suppression there was no significant difference between the 18 novice (second-year students) interpreters, 21 expert interpreters, 20 student controls and 20 bilingual controls. In the listening span task, the novice interpreters outperformed the control groups, while the professional interpreters (n = 21) did not. Although the difference was not significant, the novice interpreters obtained higher listening span scores than the professionals. The researchers argued that this finding might, in part, be caused by age and training as the novice interpreters were on average almost 20 years younger than the professionals and some of them had received memory training at school.

In the same vein, Liu et al. (2004) found no difference in the scores on a listening span test of 11 professional interpreters and 22 student interpreters although the professionals did perform better on an interpreting task. They attributed the interpreters' better performance to their superior ability in managing competing demands on limited cognitive sources. More specifically, they propose that the skill of selecting more important ideas from the speech input under highly demanding conditions and as such inhibiting less important ideas is an important strategic skill for the interpreter. This skill is thought to be a result of experience and is independent of working memory capacity. Köpke and Nespoulous (2006) proposed a similar explanation for the absence of an interpreter advantage in their study, in addition to the age factor. They argue that span tasks, measuring working memory capacity, tap into the articulatory rehearsal system of the phonological loop, while simultaneous speaking and listening impedes access to this rehearsal system (Köpke & Nespoulous 2006). Therefore span tasks might not be suited to chart interpreting-related cognitive abilities. Similarly, the contradictory findings in the interpreting literature on working memory have led Morales et al. (2015) to assert that span tasks are unable to determine whether differences between interpreters and non-interpreters stem from higher functioning in storing information, a better ability to manipulate information or a combination of both.

If the assumption is to be maintained that interpreters have better working memory skills than other language users, these skills must be mediated by other working memory functions than memory span. The executive control system in Baddeley's (2000) model might provide explanatory power in this regard. As noted earlier, the executive functions updating, inhibiting and shifting seem to be inherent to the activity of interpreting. The aforementioned contradictory results in working memory related interpreter research have encouraged scholars to pinpoint these specific executive functions of working memory. As such, the central executive, also called the attention-control system, was the focal point of attention in the study of Timarová et al. (2014). They looked into the executive functions of 28 professional interpreters. Although no consistent trends were found across all investigated features of simultaneous interpreting (syntactic processing, semantic processing, lexical processing, vocabulary richness, unique vocabulary, ear-voice span, and effect of speeds delivery), significant correlations were found between the central executive functions and certain features of simultaneous interpreting. For one, the updating function and the shifting function were found to correlate positively with lexical processing. This means that interpreters who did better in correctly translating figures during an interpreting task, obtained higher results on the updating and shifting tasks. The scores on the shifting task also correlated positively with ear-voice span scores indicating that the interpreters who held a short ear-voice span – a shorter time lag between the source text input and their output – were faster switchers. Finally, a positive correlation was established between the average number of correctly interpreted items (i.e. accuracy) and an arrow flanker task, which measures the ability to resist distractors. In another recent study on interpreters' central executive functions, 16 professional interpreters were compared to a bilingual control group. Morales et al. (2015) aimed to investigate the link between interpreting and the attention-control system by administering an updating task and an orienting task. Their results point to an interpreter advantage when it comes to updating and monitoring capacities. The interpreters were more accurate and faster than the control group. However, when the cognitive load increased, the accuracy level decreased for both the interpreter and the control group. According to Morales et al. (2015), this indicates that the storage systems of both the interpreters and the bilinguals function in a similar way. Consequently, the superior performance of the interpreters was construed as a result from executive control components of working memory such as updating and monitoring.

In the study presented below, we will further investigate the role of the attention-control system. Our main research question is whether a group of advanced language learners consisting of aspiring interpreters, translators and multilingual communicators show differences in the executive control functions of working memory before they are trained in their respective domains. If the interpreter students already demonstrate superior cognitive control at the start of their Master's training, then their executive control advantage, if we assume there is one, is not the result of an interpreter training programme or of interpreting experience. If the interpreter students show no advantage in attention-control, this could mean that executive control advantages that are attested in professional interpreters are to be attributed to interpreter training and experience.

3. Experiment

3.1. Research questions

1. Do student interpreters exhibit higher working memory storage capacity than student translators and student multilingual communicators prior to their respective training?

2. Do student interpreters exhibit better inhibition skills than student translators and student multilingual communicators prior to their respective training?

3. Do student interpreters exhibit better updating skills than student translators and student multilingual communicators prior to their respective training?

4. Do student interpreters exhibit better shifting skills than student translators and student multilingual communicators prior to their respective trainings?

3.2 Method

3.2.1. Participants

A total of 61 students enrolled at the Department of Translation, Interpreting and Communication of Ghent University took part in this study. All participants were native Dutch speakers studying two foreign languages and aged between 20 and 28 years with a mean age of 21.8 years. The participants had all completed a Bachelor's degree in applied language studies and had just begun their vocational training in either a Master's in interpreting (n = 21), a Master's in translation (n = 20) or a Master's in multilingual communication (n = 21). The Master in Translation and the Master in Interpreting are both well-known and established programmes, one focussing on written transference from one language to another and the other one focussing on oral rendition. The Master in Multilingual Communication is quite a recent programme focussing on high level proficiency in the mother tongue on the one hand and high level intercultural communication on the other hand.

Although the participants are admitted to the Master's programme of interpreting without admission test, their previous training and our colleagues' careful scouting of students that would be able to complete the interpreter programme with success, entails that this can hardly be considered a self-selection process. Before being eligible to enrol in the Master's programme of their choice, students need to obtain a Bachelor's degree in applied language studies. This Bachelor's programme is highly focussed on the practical usage of two foreign languages, with an emphasis on oral proficiency and translation from and into the foreign languages, and on flawless spoken and written Dutch as a mother tongue. As such, the academic Bachelor's programme is considered a preparatory programme for a Master's in translation, interpreting or multilingual communication. In the third Bachelor year, students are further prepared for the different Master's programmes through a compulsory term abroad in addition to courses in (academic) writing skills and speaking skills, including sight translation classes. Over the course of this three-year Bachelor training about 60% of students drop out during some stage of the programme. Before selecting a Master's programme, students are thoroughly informed about the content of the three Master's programmes. Students with near-native speaker competence in their foreign languages who show an interest in interpreter training and whose potential for interpreting has been confirmed by interpreting trainers, are encouraged to enrol. Others are dissuaded from taking up interpreting. As a result of this process, the MA programme in interpreting consists of a selected number of students every year. In this programme students are thoroughly trained in consecutive interpreting and familiarized with different liaison interpreting contexts such as legal and medical settings or business settings. In addition, they acquire the skill of chuchotage interpreting throughout a range of different situations and topics. They have the opportunity to practice in the booth, a skill which is further perfected in the postgraduate conference interpreting programme. Obviously, not all of these graduated interpreters will end up in the postgraduate programme or on the interpreting market as they tend to swarm out into different fields such as education or communication.

3.2.2. Materials and procedure

Data collection took place in September and October of the academic year 2014-2015. Participants were informed about the content and the length of the test battery and were asked to sign an informed consent form. Before each test, the participants were explained orally and in their native language what they were expected to do in the ensuing assignments. For the computer-based tasks, the instructions also appeared in print on the screen, again in their native language. These computer tasks were presented on an IBM-compatible laptop computer with a 15-inch screen, running XP. Subjects were tested individually in a quiet room by a research assistant who remained present during the entire procedure, which took on average sixty minutes. The task order was counterbalanced across participants to avoid a fatigue effect which could result in slower or less accurate responses on any particular task.

The participants performed two types of tasks: (a) one memory storage capacity task, i.e. a digit span task (Wechsler 1997) and (b) four tasks tapping into executive control functions: a 2-back task (Kirchner 1958), a Simon task (Simon & Rudell 1967), the Attention Network Test (Fan et al., 2002) and a colour-shape switch task (Rogers & Monsell 1995). These tasks were selected on the basis of their widespread use in working memory research and their relevance within the interpreter context. Both the reaction times and the accuracy rate was registered and used in the analyses. The scoring method is specified in the results sections. In what follows the test instruments will be described in detail:

Digit Span Task

The digit span task was included to measure participants' storage capacity. Both forward and backward spans were measured. It has to be noted that the forward span only measures storage capacity, whereas the backward span tasks requires executive control (Engle, Laughlin, Tuholski & Conway, 1999). The task was adapted from the WAIS-III (Wechsler 1997) and consisted of 16 sequences of digits of increasing length in the forward condition and 14 sequences of digits of increasing length in the backward condition. The shortest sequence contained two digits, the longest nine. Each trial comprised two sequences of the same length. In the forward span task, participants were read a sequence of digits and asked to orally recall the digits in the same order. The sequences were read at a steady pace by an experienced administrator. In the backward span task, they were asked to recall the digits in reverse order. The task ended when all sequences were read or when the participants made errors in both sequences of the same length. The scoring of the sequences was binary, in other words, minor errors were not tolerated. Sequences were identical for all participants.

Simon Task

A coloured Simon task was used to assess participants' ability to inhibit automatic responses. Coloured dots appeared either on the left or right side of the screen and participants with an even participant number were asked to press the left key on the keyboard when a green dot appeared, and the right key when a red dot appeared. For uneven participant numbers, this instruction was reversed – i.e. press right when a green dot appears and press left when a red dot appears – in order to counterbalance the response mapping across participants. The combination of position and colour constituted either a congruent trial or an incongruent trial.

Each trial began with a fixation cross that remained visible for 600 ms, followed by a clear screen, after which the dot appeared. The presentation of the coloured dot lasted until the participant's response or up to 1500 ms. There was a 500 ms blank interval before the next fixation period. The experiment consisted of 10 randomised practice trials and two blocks of 100 randomised experimental trials. Half of all trials presented the coloured dot on the same side of the associated response key, and half on the opposite side. Stimuli were presented via Tscope software (Stevens, Lammertyn, Verbruggen, & Vandierendonck 2006) on an IBM-compatible laptop computer with a 15-inch screen, running XP.

Attention Network Test (ANT)

A shortened ANT-version was employed, measuring the *executive network* (which has the ability to detect and solve conflict; i.e. the inhibition function) and the *orienting network* (which selects information from sensory input). Participants were shown five arrows and were asked to indicate the direction of the middle arrow. The experimental design contained two within-subject factors: flanker type (congruent and incongruent) and cue type. Cues assessed orienting skills and were presented at the location of fixation (centre cue) or at the location of the upcoming target (spatial cue). Sometimes, no cue was presented. Comparing congruent and incongruent trials measured the executive network, comparing central and spatial cue trials quantified the orienting network.

A session consisted of a 6-trial demo block, a 12-trial full feedback practice block, and three experimental blocks of 48 randomised trials. Each condition was shown an equal amount of times (once during the demo, twice during practice, eight times per experimental block). Each trial consisted of five events: (1) a fixation of a random variable duration (400-1600 ms), (2) a cue for 100 ms, (3) another fixation of 400 ms, (4) target arrow and flankers above or below fixation until response or up to 1700 ms, (5) clearing the screen after response. In the no cue condition, there was no step two or three. Participants were instructed to focus on the fixation cross and respond as quickly and accurately as possible. They pressed the left button of a touchpad with their left hand when the target pointed to the left, and the right button of that touchpad with their right hand when the target pointed to the right. Stimuli were presented via E-Prime on an IBM-compatible laptop computer with a 15-inch screen, running XP.

Colour-shape Switch Task

This task evaluated task *shifting* or *switching* abilities. It consisted of two blocked conditions and a switch condition. In the colour block condition, participants were asked to respond to the colour of an image, and in the shape block condition, they were asked to respond to its shape. The switch condition required participants to respond to either shape or colour depending on the cue.

The images in this task were either blue or yellow triangles and squares. In the blocked colour condition, participants with an even participant number were asked to press top left for a yellow image and bottom left for a blue image. For participants with uneven participant numbers, the instruction was reversed in order to counterbalance the response mapping. In the blocked shape condition, participants had to press the top left (bottom right) button for a triangle and bottom left (top right) for a square. They had to employ the exact same response buttons in the switch condition. The blocked conditions each consisted of 8 practice trials and 34 experimental trials. The switch condition consisted of two blocks of 47 trials (94 trials in total). Each block contained 20 switch trials, randomly ordered with a maximum of 4 consecutive trials (also called stay trials, i.e. with no switch from colour to shape or vice versa) of the same type. In this task we are particularly interested in registering how well participants deal with the possibility of having to switch between tasks. This is called the Mix Cost and is calculated by subtracting overall scores in the blocked condition, where there is no possibility of switch, from stay trial scores in the switch condition, where the possibility of having to switch exists but is not utilized. In addition, we also want to know how well they coped with actually having to switch, which is labelled the Switch Cost and is calculated by subtracting switch trials scores from stay trials scores in the switch condition.

The experimental phase was always preceded by a practice phase of 10 trials with three switches. The cue indicating to which feature participants were expected to respond was either a multicoloured circle (colour) or a white octagram (shape).

Throughout the entire experiment, presentation of a stimulus lasted up to 2500 ms or until a response was given. Each stimulus was introduced by a fixation cross, which remained on screen for 600 ms, and followed by a 300 ms interval before another fixation appeared. In the switch condition, a 400 ms cue (either shape or colour) followed the fixation and preceded the stimulus. Stimuli were presented via E-Prime on an IBM-compatible laptop computer with a 15-inch screen, running XP.

2-back Task

The 2-back task was employed as a measure of *updating* working memory. It is a widely used task for assessing updating skills while minimizing the storage and verbal component

(Morales et al. 2015). It consisted of 25 black and white line picture drawings of daily objects that provide high naming agreement in Dutch, based on the norming study by Severens, Lommel, Ratinckx, and Hartsuiker (2005).

Drawings were presented individually and centred on the computer screen. Each picture was shown for 2000 ms and was followed by a blank screen of 1000 ms. Participants were required to indicate as fast and as accurately as possible whether a presented item matched the one presented two positions before by pressing the left (i.e. mismatch) or right key (i.e. match) on the keyboard. They were not informed about the presence of lures.

The task comprised two blocks of 94 trials each with a pause after 47 trials. The first block contained 30 match trials (i.e. the picture matched the picture presented two positions before) and 60 mismatch trials (i.e. the picture did not match the picture presented two positions before). The second block contained 13 $n + 1$ lure trials (i.e. target item does not match the item two positions back but does match the item three positions back). There were 30 match trials, 47 mismatch trials, and 13 lures in this last block. Hence, the number of 'yes' and 'no' responses was kept equal across blocks. The occurrence of a particular drawing on a match, mismatch, or lure trial was counterbalanced across all stimuli. The list order was fixed and exactly the same for each participant. A practice block of 47 trials preceded the experiment and did not contain any lure trials. Stimuli were presented via E-Prime on an IBM-compatible laptop computer with a 15-inch screen, running XP.

3.3. Results

Before analysing participants' performance in the different tasks, we looked at the demographics of the participant population of multilingual communicators (MC), translators (TRANS) and interpreters (INT). These are presented in Table 1. As the participants' age range is small, there was no significant difference in age between the three groups. In all three groups, the male participants were outnumbered by the female participants as is often the case in (applied) linguistics degrees. Yet, the male/female ratio was not significantly different between the three groups.

Table 1. Demographic information on the three groups, with comparison results. Standard deviations are between parentheses.

	MC	**TRANS**	**INT**	Test	*p*
N	21	20	21		
Male/female ratio	2/19	5/15	6/15	$Chi^2(2) = 2.59$	.274
Age (in years)	21.9 (2.5)	22.1 (1.4)	22.1 (2.1)	$F_{2,59} < 1.0$	.904

Digit Span Task

For the measurement of participants' storage capacity, which is the number of digits they were able to repeat, both the forward and backward span of the digit span task were taken into account and the span effect was calculated. Backward span tasks are considered more challenging than forward span tasks as they require executive control. The span effect is the difference between the score on the forward span task and the score on the backward span task. It has to be noted that a small span effect does not necessary equal better working memory. For example, if a participant obtained a very high score on the forward span task and a moderately high score on the backward span task, this person would have a larger span effect than someone who received low scores on both tasks. Therefore, the span effect merely provides an indication of the impact of the more difficult condition on the participant's performance. The highest achievable score for the forward span task is 16, for the backward span task the maximum score is 14. A repeated measures ANOVA and subsequent planned comparisons were used to determine differences between the three groups. The scores for the three groups can be found in Table 2.

Table 2. Digit span scores for the three groups (MC, TRANS and INT). Standard deviations are between parentheses.

Test	MC	TRANS	INT
Span			
Forward	10.0 (1.6)	10.5 (1.5)	10.0 (1.9)
Backward	7.2 (2.1)	6.5 (1.2)	7.6 (2.1)
Effect	2.8 (1.7)	4.0 (1.9)	2.4 (1.8)

Span analyses by means of a 3 (Group: MC, TRANS, INT) x 2 (Span: Forward, Backward) ANOVA yielded a main effect of Span ($F_{1,58}$ = 173.93, p < .001, η_p^2 = .750), with higher scores on forward spans than on backward spans. This chimes with the generally accepted assumption that backward span tasks are more challenging. There was no main effect of Group ($F_{2,51}$ < 1.0, p = .796, η_p^2 = .008), but there was a Span*Group interaction ($F_{2,51}$ = 4.08, p = .022, η_p^2 = .123). Planned comparisons demonstrated a significant difference between the group of translators and the group of multilingual communicators (t_{58} = 2.12, p = .039) and between the group of translators and the group of interpreters (t_{58} = 2.73, p = .008). In both cases, the group of translators had a larger span effect. As these populations had comparable scores on the forward span task, the difference in span effect was caused by a poorer performance of the translator group on the backward span task. This means that the interpreter group and the multilingual communicator group were less affected by the more difficult backward condition than the translator group.

Executive Control Tasks

With regard to the four executive control tasks, analyses were performed on mean reaction times (RT) and accuracy percentages (ACC). For each task, outlier RTs were trimmed for individual participants by calculating the mean across all trials and excluding any response deviating by more than 2.5 SD of that mean. This procedure eliminated 3.1% of all Simon data, 2.1% of all ANT data, 3.8% of all switching data, and 3.6% of all 2-back data. Due to a technical problem, Simon and Switch scores were not recorded for one student translator and two student interpreters. To determine differences between groups on any of the tasks, repeated measure ANOVAs with Group as the independent variable and subsequent planned comparisons (where necessary) were carried out. The Levene Statistic indicated whether or not equal variances could be assumed. All task data are presented in Table 3.

Table 3. Test results for the three groups (MC, TRANS and INT), with reaction times (RT) in ms and accuracy (ACC) in percentages (standard deviations are between parentheses).

Test	MC	TRANS	INT
Simon			
RT			
Congruent	406 (57)	395 (48)	378 (46)
Incongruent	438 (60)	421 (41)	410 (48)
Congruency effect	32 (21)	26 (22)	33 (11)
ACC			
Congruent	98.1 (1.8)	97.9 (2.1)	96.9 (2.2)
Incongruent	96.1 (2.5)	95.6 (3.8)	93.6 (5.0)
Congruency effect	1.9 (2.5)	2.3 (3.7)	3.3 (4.4)
ANT			
RT			
Congruent	510 (58)	487 (51)	491 (60)
Incongruent	608 (67)	575 (66)	581 (75)
Congruency effect	98 (42)	88 (27)	90 (28)
Orienting effect	60 (26)	63 (16)	59 (21)
ACC			
Congruent	99.5 (0.8)	99.3 (1.4)	99.5 (0.7)
Incongruent	94.8 (5.4)	95.1 (5.4)	93.9 (6.8)
Effect	4.7 (5.3)	4.2 (5.4)	5.6 (6.8)
Orienting effect	1.7 (3.0)	1.9 (5.5)	2.7 (5.5)
Colour-shape Switch			
RT			
Mix Cost	165 (126)	182 (119)	210 (155)
Switch Cost	164 (112)	132 (97)	127 (119)
ACC			
Mix Cost	5.1 (4.5)	6.5 (12.5)	6.7 (12.0)

Switch Cost	2.6 (6.4)	5.4 (6.6)	2.4 (4.7)
2-back			
RT			
Match	728 (131)	730 (176)	748 (177)
Mismatch	672 (84)	686 (85)	714 (142)
Lure	813 (190)	882 (196)	877 (225)
ACC			
Match	95.4 (14.6)	98.6 (1.4)	95.4 (14.6)
Mismatch	83.5 (14.4)	81.6 (17.6)	83.5 (14.4)
Lure	70.3 (16.7)	70.8 (17.8)	70.3 (16.7)

Simon task.

The data of three participants from the multilingual communicator group were not analysed, because their accuracy scores were all 0.0%, probably due to pressing the wrong keys.

A 3 (Group: MC, TRANS, INT) x 2 (Congruency: Congruent, Incongruent) ANOVA on RTs showed a main effect of Congruency ($F_{1,51} = 138.61$, $p < .001$, $\eta_p^2 = .731$), with faster responses to congruent trials which is customary in this type of task. The main effect of Group ($F_{2,51} = 1.37$, $p = .261$, $\eta_p^2 = .051$) and the Congruency*Group interaction ($F_{2,51} < 1.0$, $p = .447$, $\eta_p^2 = .031$) were not significant. In other words, all groups had similar RTs and similar Simon effects.

The same ANOVA was run on accuracy scores and yielded a main effect of Congruency ($F_{1,51} = 25.01$, $p < .001$, $\eta_p^2 = .329$), with higher accuracy rates on congruent trials which is considered normal. The main effect of Group was not significant ($F_{2,51} = 2.57$, $p = .087$, $\eta_p^2 = .092$), nor was the Congruency*Group interaction ($F_{2,51} < 1.0$, $p = .527$, $\eta_p^2 = .025$).

Attention Network Test

RTs were analysed via a 3 (Group: MC, TRANS, INT) x 2 (Congruency: Congruent, Incongruent) x 3 (Cue: No, Centre, Spatial) ANOVA. This provided a main effect of Congruency ($F_{1,59} = 487.69$, $p < .001$, $\eta_p^2 = .892$) and Cue ($F_{2,58} = 331.18$, $p < .001$, $\eta_p^2 = .919$), but not of Group ($F_{2,59} = 1.28$, $p = .285$, $\eta_p^2 = .042$). RTs were faster for congruent trials as opposed to incongruent trials, and RTs were also faster when a spatial cue was present. RTs were slowest on trials with no cue. Congruency or Cue never interacted with the effect of interest, namely Group (all *p*s > .350). Hence, there was no Group effect for orienting.

The ACC analysis was almost identical, with a main effect of Congruency ($F_{1,59} = 41.69$, $p < .001$, $\eta_p^2 = .414$) and Cue ($F_{2,58} = 5.95$, $p = .004$, $\eta_p^2 = .170$), but no effect of Group ($F_{2,59}$ <

1.0, p = .857, η_p^2 = .005). ACC was higher for congruent trials, and the accuracy rate was also higher when a spatial cue was present. Again, Congruency or Cue never interacted with Group (all *p*s > .610): no effect for orienting was found.

Colour-shape Switch Task

The data of two participants from the translator group were not analysed, because their accuracy scores were around 0.0-1.0%, probably due to pressing the wrong keys. Mix Cost and Switch Cost were calculated by subtracting overall scores in the blocked condition from stay trial scores in the switch condition, and subtracting switch trials scores from stay trials scores in the switch condition, respectively.

For RTs, the 3 (Group: MC, TRANS, INT) x 1 (Mix Cost or Switch Cost) ANOVAs yielded no differences between groups for either Mix Cost or Switch Cost (both times $F_{2,54}$ < 1.0, *ns*).

For accuracy, analyses were the same and produced similar results (Mix Cost: $F_{2,54}$ < 1.0, *ns*, Switch Cost: $F_{2,54}$ =1.49, p = .235). In other words, the three groups performed similarly, both in terms of response times and accuracy rates.

2-back Task

For the RT analysis, a 3 (Group: MC, TRANS, INT) x 3 (Condition: Match, Mismatch, Lure) ANOVA was carried out. There was a main effect of Condition ($F_{2,58}$ = 38.70, p < .001, η_p^2 = .572), with the fastest RTs for mismatch trials and the slowest for lure trials. There was, however, no effect of Group and no interaction with Group (both *F*s < 1.0, *ns*).

ACC analyses demonstrated a main effect of Condition ($F_{2,58}$ = 139.09, p < .001, η_p^2 = .827), with the highest ACC for match trials and the lowest for lure trials which is the standard effect of load. Again, there was no effect of or interaction with Group (both *F*s < 1.0, *ns*). In other words, there was no significant difference between the performances of the three groups.

Correlations

In order to explore the relation between storage capacity on the one hand and processing and control skills on the other hand correlations were calculate between the test data of the three groups combined. This division between processing elements and control elements within the executive tasks is made as processing occurs on a more automatic level whereas the control tasks – as the term indicates – require the participant to have control over the cognitive processes. Pearson correlations were performed on overall scores in order to investigate (1) the relation between working memory storage capacity (i.e. forward digit span) and all processing tasks (i.e. the congruent conditions in the Simon task and the ANT, the blocked conditions in the switch task, and the match and mismatch trials in the 2-back task; see Table 4), and (2) the relation between working memory storage capacity and all control tasks (i.e. the Simon and ANT effect, the mix and switch cost in the switch task, the lure trials in the 2-back, and the backward digit span; see Table 5).

Table 4: Pearson correlations between the forward WM span score and the processing measures

Measure	Forward span score		Forward span score
RT		*ACC*	
Simon congruent	-0.001	Simon congruent	0.045
ANT congruent	-0.234	ANT congruent	-0.12
Switch mono	0.015	Switch mono	0
Switch total	0.002	Switch total	0.05
2-back match	0.073	2-back match	-0.02
2-back mismatch	-0.094	2-back mismatch	0.138

Table 5: Pearson correlations between the forward WM span score and the executive control measures (including the backward span score)

Measure	Forward span score		Forward span score
Backward span score	0.438**		
RT		*ACC*	
Simon effect	-0.014	Simon effect	0.129
ANT effect	-0.267*	ANT effect	0.092
Switch cost	-0.126	Switch cost	0.025
Mix cost	0.04	Mix cost	0.045
2-back lure	0.094	2-back lure	0.307*

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

* Correlation is significant at the 0.05 level (2-tailed).

The correlational analysis of the processing tasks with working memory capacity (i.e. forward digit span) yielded no significant correlations, neither for reaction times or accuracy. A similar analysis of the control tasks and working memory capacity showed significant correlations between WM forward and WM backward ($r = .438$, $p < .001$), between WM forward and the ANT effect for RTs ($r = -.267$, $p = .038$), and between WM forward and accuracy on lure trials in the 2-back task ($r = .307$, $p = .016$).

4. Discussion

In the following discussion of the results, we will attempt to relate our findings to those that have been reported in the literature. However, as no comparative study of pre-training differences between interpreter students and other language students has yet been conducted, we are limited to a comparison with studies contrasting professional interpreters to bilingual controls.

In answer to the first research question, which looks into the storage capacity of the three participant groups, the interpreter group and the multilingual communicator group had the smallest span effect, which in this case means that the backward condition was less challenging for them than for the translator group. In other words, when only storage capacity is measured (forward span task) the three groups perform equally well but when executive control is required in combination with this storage capacity, the student interpreters and student multilingual communicators perform significantly better than the translators. This points to a small cognitive advantage for the student interpreters compared to the student translators, and they seem to share this advantage with the students of multilingual communication. This may be explained by the nature of the task: the listening and speaking component of the digit span task involved are probably better aligned with the competences of students who opt for vocational trainings with a strong oral component.

Regarding the second research question concerning an interpreter advantage for the inhibition function, the analysis of the data showed no significant differences between the three populations: not for the ability to suppress automatic responses as measured by the Simon task nor for the ability to ignore irrelevant stimuli, measured by the ANT. This could indicate that inhibiting is a skill acquired through training. In interpreting training students learn to avoid interference from distractors such as their own voice or background sounds. Furthermore, as interpreting experience grows students manage to achieve an optimal ear-voice span. This delay in the production of the target output is a helpful tool in resisting automatic responses such as starting a syntactic structure which will be hard to complete in the target language. Timarová et al. (2014) provided some evidence for the trainability of the inhibition function as they found an improvement of inhibition skills in older and consequently more experienced interpreters. The third research question concerned a comparison of updating skills between student interpreters, student translators and students of multilingual communication. There is no significant difference in updating abilities between the three groups. The assumption that interpreter students would do better than their peers when it comes to monitoring incoming information and replacing previous information with new information has to be discarded. Differences in updating performances between professional interpreters and bilingual controls or between professional interpreters and student interpreters found in other studies might be the effect of training and experience. Some support for this claim can be found in Morales et al. (2015)'s study in which it was shown that expertise in interpreting enhances updating skills.

The fourth research question looked into the shifting abilities of the three participant groups. No difference between the shifting abilities of student interpreters on the one hand and student translators and students of multilingual communication on the other hand was found. The ability to switch attention between two separate tasks is part and parcel of the interpreting performance, which is why (student) interpreters are trained to do so during their formation. Indeed, Yudes et al. (2011) found superior shifting abilities in professional interpreters, compared to bilinguals with comparable high memory span. The fact that these better shifting abilities are not yet present in our interpreter students might indicate that shifting skills can be developed during training.

Summarizing we can state that the results of the different tests do not point to an executive control advantage for the student interpreters. This might imply that attested cognitive advantages for interpreters in previous studies were the result of interpreter training.

On the other hand, our results could reflect the absence of an interpreter advantage. Despite the fact that Hervais-Adelman, Moser-Mercer & Golestani (2015) found that training in simultaneous interpretation induces functional cerebral plasticity in the caudate nucleus – a structure that is thought to control the access to two lexico-semantic systems during interpreting – we should consider the possibility that the presumed interpreter advantage does not exist. It is conceivable that studies that have found it in the past were subject to sampling errors, observer-expectancy effects, or an increased likelihood of extreme values due to small samples.

Another possible explanation for the lack of differences in our study might be the modest number of participants in each group, which could cause a lack of power. A sensitivity analysis using GPower (Faul, Erdfelder, Buchner & Lang, 2009) revealed that a study with our design and sample sizes has 70 % power to detect true effects of size .35 assuming normality, equal variances, and a 5% significance level. This indicates that the study at hand has inadequate power to detect small or medium effects.

Lastly, the correlational analysis revealed a positive significant correlation between the scores on the forward span task and accuracy on lure trials in the 2-back task. As these lure trials are actually 3-back trials – which means that the target matches the stimulus presented three positions before but not two positions before – this result shows that the better participants' working memory storage capacity was, the better they could retain the pictures' positions. We also found a negative correlation between the forward span task and the ANT effect, indicating that those who performed better on the recall task had a smaller ANT effect (i.e. they were better at resisting the interference of irrelevant stimuli). The lack of consistent positive correlations between storage capacity and processing and control tasks suggests that storage capacity and executive functions, although related to some extent, do not tap into the same functions of working memory. This ties in with the results reported by Michael et al. (2011) who found no correlation between a digit span task and a Stroop task measuring inhibition.

5. Conclusion

The main aim of this study was to compare the executive control functions of three groups of advanced language learners, who enrolled into three Master's programmes (translation, interpreting or multilingual communication). For many decades, interpreters have been assumed to possess superior working memory skills compared to other bilinguals. However, as interpreter research in the past has not always been able to demonstrate this interpreter storage advantage, recent research has started to focus on executive functions of working memory rather than storage capacity. While these studies have been able to establish an interpreter advantage in a number of executive control capacities (Yudes et al. 2011, Morales et al. 2015), the question remains whether this superiority is the effect of interpreter expertise or rather the result of the interpreters' selection process. Since executive functions are among the most heritable psychological traits (Friedman et al. 2008), it is clear that they are not solely the effect of training and that pre-training differences are plausible. As it is generally assumed that people tend to choose a profession that suits their cognitive skills (Turner & Bowen 1999), the interpreter profession might be – unconsciously – more appealing to those with better developed executive control. Against this backdrop, the current study aimed to establish whether cognitive control advantages can already be attested at the start of interpreter training. This was done by comparing working memory storage and executive control functions of student interpreters at the start of their Master's programme with those of their peers who embarked on a Master's programme in translation or multilingual communication. As such, and to our knowledge, this study is the first to investigate executive control functions in student interpreters prior to professional training.

In our study only the digit span task was found to differentiate between the participant groups, more specifically when storage capacity and executive control needed to be combined. However, this combination of storage and executive control is also required in the other tasks, which leads us to assume that the oral aspect of the task might have contributed to this result. Both student groups who have chosen a training with a strong oral component (interpreting and multilingual communication) outperform the student group with a preference for written language (translation). The overall trend of the results of this study suggests that student interpreters are, on an executive control level, not better equipped to undertake interpreting training than the other advanced language learners who took part in the experiment.

The absence of reliable differences between interpreting students and other language students in terms of executive control and storage capacity suggest caution in the use of cognitive tests when screening potential interpreting students. The general assumption of excellent working memory skills as being a prerequisite for interpreter training and the tradition to include the assessment of working memory skills (Timarová & Ungoed-Thomas 2008) in interpreter entrance examinations may need to be qualified.

Although the fact that our participants were not admitted to the master programme through a formal entrance examination could be considered a limitation, we argue that the gradual selection process that preceded their choice to enter the MA in interpreting has reduced the likelihood of unsuitable interpreter candidates. Furthermore, we would like to argue that although the cognitive demands in this MA in liaison interpreting might be slightly different from those in a conference interpreting programme as the focus is more on consecutive interpreting than on simultaneous interpreting, they are no less great. We can report that in this particular cohort all participants completed their respective training – either in the first or the second session of exams – and have been certified accordingly. A second limitation concerns the relatively small number of participants due to the availability of suitable participants and the labour-intensiveness of the data collection. But compared to other studies of this kind, twenty participants per experimental group seems to approximate the norm. Finally, as executive control tasks traditionally use visual stimuli, the overreliance on visual input might have biased the results vis-à-vis the cognitive style preference of participants.

We realize that this study is only a first step in unravelling the cognitive mysteries of interpreters and that the timing of the experiment, i.e. in the very beginning of training, might account for the lack of differences between the groups. That is why we have planned a follow-up study in which the student interpreters will be re-tested after completing their interpreter training in order to investigate the effect interpreter training has had on their executive control functions. At this time, we will also take into consideration whether or not they have enrolled in a postgraduate training in conference interpreting. Also, their scores on the different executive control functions will be compared to those of experienced translators, interpreters and multilingual communicators who will undergo the same battery of tests.

We hope that this contribution will spark interpreting scholars' interest in the attention-control functions in which interpreters are often expected to excel, even prior to training. Further research in this area could not only prove beneficial to the field of aptitude testing but also to interpreting didactics. It may lead to more expertise on how to effectively select candidates in interpreter admission tests and to the development of better adjusted memory exercises in interpreter training.

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