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The effect of interpreter training on working memory executive control

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PREFACE

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1. INTRODUCTION

An interpreter is required to recall and retain a certain amount of information and has to be able to accomplish complex memory-related tasks in order to perform well as a professional. Accordingly, interpreters are widely believed to have superior memory skills and more specifically, enhanced working memory (WM), which is generally defined as “storage buffers that retains information briefly, rehearsal processes that refresh the buffers an executive processes that manipulate the contents of the buffers” (Jonides, Lacey & Nee 2005, p. 2). Over the years, a fair amount of research has been dedicated to interpreters’ working memory. These studies mainly aim to provide evidence for this assumed interpreter advantage. Some studies have indeed been able to establish superior memory skills in interpreters (e.g. Padilla B., Bajo, Cañas & Padilla F. 1995; Christoffels, de Groot & Kroll 2006; Signorelli 2008). However, a number of studies have failed to establish this interpreter advantage (e.g. Liu, Schallert & Carroll 2004, Köpke & Nespoulous 2006; Timarová et al. 2014). Moreover, most studies mainly focus on storage and processing but varying research conclusions might point to a different explanation for those wide-ranging results: not storage capacity itself, but how that storage is used determines achievements. Recently, this has led researchers to turn to working memory’s executive functions as to explain an advantage for interpreters (Rosiers, Woumans, Duyck & Eyckmans, submitted). Executive functions are a set of cognitive abilities that are necessary for controlling behaviour (Pereg, Shahar & Meiran, 2013). Those functions consist of cognitive processes and behavioural competences such as “verbal reasoning, problem-solving, planning, sequencing, attentional control, resistance to interference, multitasking, cognitive flexibility and the ability to deal with novelty” (Chan, Shum, Toulopoulou & Chen 2008, p. 202). This recent shift towards executive control in the field of interpreting has been a source of inspiration for the present study. However, this study does not set out to establish differences between interpreters and non-interpreters but rather aims at gauging the effect of the interpreter training on three executive control functions through a longitudinal design.

Therefore, three executive control functions (shifting, inhibition and updating) were tested in fifteen subjects by means of four different executive control tasks and one working memory capacity task. Those three functions are selected for their relevance to interpreting. Resistance to interference (inhibition) is required in order to maintain focus while having to avoid distraction from irrelevant stimuli, such as irrelevant noise and sound. Those irrelevant factors might be unrelated to the task at hand. It stands to reason that interpreters also have to deal with resistance to interference and environmental factors. Amongst irrelevant factors could be their own voices, which can contend with the source text for their attention (Timarová et al., 2014). Resistance to automatic responses or response inhibition is a second inhibitory function. Developed routines such as automated behaviour but also triggering stimuli can lead to automatic responses. In interpreting this consists of avoiding false cognates, postponing the interpretation to attain an adequate amount of information for planning and then interpreting, in order to avoid later problems (Timarová et al., 2014). A second executive function is updating, which requires incoming information to be continuously evaluated against information that is already held in memory and is followed by changes to memory content necessary to complete the task at hand. Interpreters have to temporarily retain the incoming information while processing it, after which they have to delete that information to make room for new information (Timarová et al., 2014). Finally, the switching or shifting function requires the ability to disengage from a task in order to engage in a new one (Miyake et al., 2000). This is relevant to the interpreting context because interpreters have to use incoming information as a basis for producing their own output (Timarová et al., 2014).

In the current study, the shifting function was tested with the switch task, the updating function with the 2-back task and the two types of inhibition were tested with the Attention Network Test (ANT) and a Simon-task. The last task, a digit span task, tests the memory storage capacity when used as a forward recall task and executive functions when used as a backwards recall task. These tasks are explained in greater detail in section 3. The participants were tested at two different time points. Rosiers et al. (submitted) collected the data of these participants before they entered interpreter training. One year later, these students, who had graduated as interpreters in the meanwhile, were contacted again and re-tested on the same cognitive tasks.

Through this within-subject design, we will try to establish whether graduated students have trained their ability to retain certain series of digits (digit span), to separate tasks or to put a task on hold in order to do another task (switching). In addition, we will try to establish whether they are more capable of suppressing an automatic reflex (inhibition), whether they can neglect irrelevant information (inhibition) and whether they can compare new incoming information with information already in memory (updating). The following research questions will be discussed further in section 5 of this paper.

1. Do the interpreters exhibit significant improvement in storage capacity?
2. Do the interpreters exhibit significant improvement in updating skills?
3. Do the interpreters exhibit significant improvement in switching skills?
4. Do the interpreters exhibit significant improvement in inhibition skills?

The plan of this paper is as follows: section 2 will provide a literature review on working memory and executive control and previous research in relation to interpreters and interpreting studies. Section 3 elaborates on the methodology and more specifically, on the participants, materials and procedure. Section 4 will then discuss the results obtained, after which they will be compared to previous data, and finally, section 5 and 6 will discuss and conclude this paper.

2. LITERATURE REVIEW

2.1 Working memory and executive control

A distinction between long-term memory and short-term memory was first proposed in the Organization of Behavior by Hebb (1949). The long-term memory involved permanent changes in the nervous system, while short-term memory referred to temporary electrical activity. However, this division between long-term memory and short-term memory was met with controversy, thus in 1968, Atkinson and Shiffrin generated a very influential model that consisted of the same two components, but with a different interpretation. They proposed that, from the environment, information enters into a temporary short-term storage system, which represents a temporary storage room and serves as such to the long-term memory. In their model, however, the temporary system also received the function of working memory, which is not only useful for the execution of a complex activity such as long-term learning but also for other activities such as reasoning and comprehension.

Furthermore, Atkinson and Shiffrin (1968) classified the memory system according to two different dimensions. The first dimension includes the permanent and constitutional characteristics of the system from control processes that the subject can effortlessly adjust or recompile, and is called the memory structure. The physical and unvarying incorporated processes are included as permanent characteristics of memory. The subject can choose, compose and use control processes at will, though the processes may vary slightly depending on the situation. On top of that, it depends on the instructions, the meaningfulness of the material and the past of the subject as to how the control processes are handled. The second dimension is one that distinguishes three structural components for memory, as can be seen in figure 1: (1) the sensory register, (2) the short-term store and (3) the long-term store (Atkinson and Shiffrin, 1968). Firstly, auditory material enters the sensory register and stays there for a short amount of time. After that, it decays and disappears. Secondly, there is the working memory of the subject or the short-term store, which receives information from both the sensory register as the long-term store. Nevertheless, information in the short-term store decays similarly as in the sensory register and within a small period of only 30 seconds, all information is lost. However, by way of rehearsal, which is a control process, a limited amount of information can be managed and maintained for as long as the subject wants, so that it resides in the short-term store a little longer. Thirdly, certain information that is transferred from the short-term store ends up in the long-term store, which is a permanent storage room that holds information (Atkinson and Shiffrin, 1968).

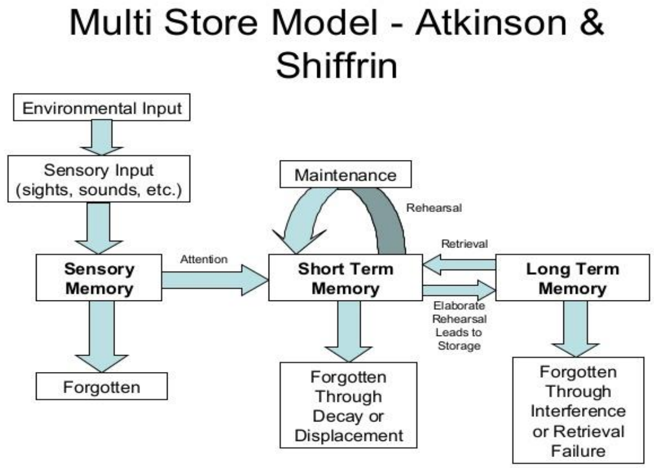

Figure 1: Multi-store Model from Atkinson and Shiffrin.

Nevertheless, the model from Atkinson and Siffrin (1968) is a general framework within which other models can be formulated. It is within this framework that Baddeley and Hitch (1974) proposed and formulated their well-known and most commonly used model of working memory in order to describe short-term memory more accurately, and as an alternative for Atkinson and Shiffrin's multi-store model, they proposed a working memory model divided into three parts.

Baddeley and Hitch (1974) researched what the function of short-term memory really is and assumed that short-term memory acts as a working memory, which is a temporary storage system that is essential to many processes such as speech comprehension, arithmetic, learning and complex reasoning (Baddeley, 1981). However, if this short-term memory is overwhelmed with secondary tasks, it would no longer be capable to comprehend or calculate and as a result, learning and reasoning and evidently, performances would be disturbed. Therefore, Baddeley and Hitch (1974) tested whether this truly happened, so their subjects had to perform tasks that required them to reason verbally, comprehend prose or learn lists of words. At the same time, as a secondary task, the subjects had to remember digit strings of six digits. There was a slight decrease in performance when comprehending prose, reasoning and learning because of the secondary task, but surprisingly little performance was disturbed although the secondary task together with the digit span should have occupied the short-term memory almost completely. After this, Baddeley and Hitch modified their view of short-term memory and changed it to the concept of working memory. Their model could then serve as a framework for more detailed analyses of working memory.

The first subcomponent of Baddeley and Hitch's model is the central executive and the other two subcomponents, which are the phonological loop and the visuospatial sketchpad, depend on this central executive (see figure 2).

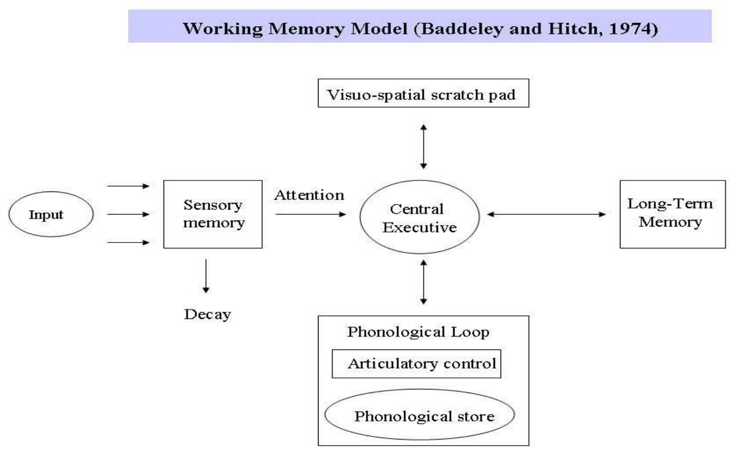

Figure 2: Working Memory Model from Baddeley and Hitch.

The phonological loop (Baddeley, 2003) deals with verbal and auditory information and stores and rehearses speech-based information. To acquire vocabulary, either native or second-language, the phonological loop is a vital precondition (Baddeley, 1992). The phonological loop is used to store any articulated information and can efficiently connect results. Though it is not essential for comprehension, it supplies an additional information source important in situations where high levels of accuracy are required (Baddeley, 1979). The visuospatial sketchpad processes and manipulates visual information . More recent, a fourth component was proposed: the episodic buffer (Baddeley, 1992), which is a passive store with limited capacity.

The temporary storage enables the components of working memory to interface with information from perception and long-term memory. The episodic buffer can hold about four multidimensional chunks, combining visual and auditory information and can be accessed through "conscious awareness" (Baddeley 2010, p. 138).

The most important component, however, is the central executive, which seems to be the most complex and least explored component of working memory and it can manipulate control processes and integrate increasing peripheral systems. The central executive forms the control centric of the system and selects and operates various control processes and it can remove some of the storage demands of the subsidiary systems the phonological loop and the visuo-spatial sketchpad (Baddeley, 1979). It is an attentional-controlling system that allows the maintaining or suppressing of information and to coordinate or switch between tasks (Baddeley, 1992; Engle, 2002). Conway and Engle (1994) added to this attentional system as being important to the inhibition of irrelevant information and for activating and maintaining information. The storage components of working memory were tested in several studies with simple storage tasks, that particularly target storage capacity of working memory and complex tasks, which combine storage and processing. Complex tasks, such as the reading span task where the subject had to read a few sentences and recall the last word of each sentence, is what connected working memory and higher cognitive processes while simple storage tasks reveal a weaker relationship with cognitive processes (Timarová et al., 2004).

Engle's research (2002) showed that when individuals are prevented from using the central executive, they do not perform better if they possess larger working memory capacity, thus concluding that individuals with a larger working memory capacity use the central executive for information maintenance. Little research was done in regard to the central executive but Baddeley (1996) outlined four functions it is assumed to fulfil: the dual tasking function (coordination of two tasks), the shifting function (switching of retrieval strategies), the inhibition function (selective attention and stimulus inhibition) and the updating function (holding and manipulation of information in long-term memory). Those executive functions are cognitive abilities that enable behaviour directed towards attaining a certain goal (Pereg et al., 2013), but there is not yet a consensus about the taxonomy of executive functions. However, a commonly used taxonomy is that of Miyake et al. (2000). They created a theoretical framework after investigating the psychometrical relationship between tasks used for gauging executive control. Their research resulted in the identification of three control functions that are separable: shifting, inhibition and updating.

Moreover, Miyake, Just and Carpenter (1994) argued that individuals who are more efficient in executing cognitive tasks are believed to have larger working memory spans. Simultaneous interpreting is a complex cognitive task that places remarkable demands on language processing and memory because it requires the handling of many processes simultaneously. New input is constantly offered and must be understood and stored in the memory, and on top of that, segments must be formulated into another language (Padilla et al., 1995). Language comprehension and production occur simultaneously with simultaneous interpreting, which leads to more difficult conditions for interpreters (Christoffels et al., 2006). Therefore, trained interpreters are sometimes believed to have superior cognitive abilities in order to cope with those remarkable demands. Working memory and executive control have been researched profoundly in several studies that are trying to relate interpreting to enhanced working memory skills or executive control. Further on, we will therefore discuss research that has been conducted in relation to simultaneous interpreting.

2.2 Working memory and executive control in simultaneous interpreting

As interpreting is a complex and demanding cognitive task, interpreters are believed to have superior cognitive abilities. However, there are many different studies on working memory in relation to interpreting with varying results. Some say that interpreters have indeed more advanced cognitive skills and enhanced working memory, while others claim the opposite. First, the studies with favourable outcomes for enhanced skills with interpreters will be discussed, after which the studies that did not corroborate this will be considered.

Christoffels, de Groot and Kroll (2006) compared performances of twelve trained interpreters to forty bilingual university students on basic language and working memory tasks. The tasks that were used are believed to employ certain cognitive abilities that are important for simultaneous interpreting, such as producing and comprehending language and dealing with a “time lag” (p. 325) between input and output because languages have different word orders. They assessed both native (Dutch) and second language (English) competence and used different memory tasks: a reading span task and a word span task that consisted of 147 English and 147 Dutch words. The words that were presented to the subjects had to be repeated in the same order. A speaking span task was implemented as well, as interpreting involves spoken language production. The task consisted of three sets of two to five words that the participants had to read and remember, after which they had to list all words in a set and create a grammatically correct sentence with one word of each set. On top of that, they had to perform two on-line processing tasks, picture naming and word translation tasks and two control tasks, a basic non-linguistic reaction time test and an English vocabulary test. Interpreters performed better on translation and picture naming tasks (for English). The only task on which they performed equally was the Dutch picture naming, which leads to the conclusion that efficient lexical retrieval is not only relevant to interpreting but is mediated by general language proficiency. However, on other tasks, interpreters were quicker and more accurate on language performance and outperformed the university students on memory capacity. Christoffels et al. (2006) suggest that several components of simultaneous interpreting might be the cause of superior short-term and working memory skills of interpreters and that increased cognitive control might play an important role when having to manage two languages.

Other studies have also suggested that interpreters have advanced skills on language and memory tasks and that they outperform other groups of participants. For instance, Padilla et al. (1995) determined that interpreters perform superiorly on digit and reading span tasks when compared to non-interpreters and in 2000, the same researchers compared interpreters with 10 interpreter trainees, 8 bilinguals without interpreting experience and 10 monolinguals. Interpreters responded more quickly on semantic categorization tasks where the subjects received a word and a category and they had to decide whether the concept belonged to the category and on non-words (i.e. words without meaning) in lexical decisions.

In 1994, Darò and Fabbro focussed on short-term retention in simultaneous interpreting and emphasized the complexity in cognitive skills that come with interpreting. Twenty four beginner interpreters were required to execute a digit span task after listening in three different conditions, while shadowing (i.e. an auditory tracking task), with articulatory suppressions (i.e. subjects have to repeat a certain sound while they are presented with words they will have to recall) and while simultaneously interpreting. Simultaneously interpreting caused decreased performances on the digit task while in other conditions the subjects scored better. This indicates that interpreting is the most complex one because of phonological interference, which is very common with foreign languages: the interference consists of a natural inclination to hear words in terms of the sounds of the mother tongue. Interpreting professionally could therefore lead to the development of the ability to resist this phonological interference while performing short-term memory tasks and in tasks that enhance cognitive demands by way of phonological interference. On top of that, Fabbro and Darò (1995) discovered that detrimental consequences of delayed auditory feedback, i.e. experiencing difficulties because of a small time delay between speech and auditory perception, were an interfering factor for participants with no simultaneous interpreting experience but not for interpreter trainees.

In 2008, Signorelli used four tasks that deconstruct working memory to determine the differences between interpreters and non-interpreters. Complex storage and processing was tested via a reading span task and phonological working memory was tested with non-word repetition tasks and articulation rate tasks, which measure the speaking rate and exclude all pauses. A cued recall task (at the time of recall, the subjects receive a hint or a cue) was also used to investigate phonological recall. Older (46 to 81 years) and younger (23 to 38 years) individuals were tested: 11 older non-interpreters, 12 younger interpreters and 11 younger non-interpreters. Age, profession and the nature of the task caused different performances. Signorelli (2008) concluded that interpreters outperform non-interpreters when it comes to complex storage and processing and phonological memory. Thus, the reading span and non-word repetition demonstrated higher performance for interpreters. In both cases, age had no effect. With cued call, however, age did matter: primacy effects (i.e. "better recall of list-initial items" [Signorelli 2008, p. 2]) showed with younger participants. The two interpreter groups showed no differences on the phonological and semantic storage (cued recall) or on phonological processing (articulation rate).

Another study (Tzou, Eslami, Chen & Vaid, 2011) was conducted to determine the influence of language proficiency and interpretation training degree on simultaneous interpreting performance and working memory capacity between Mandarin and English student interpreters that had either had one year or two years of training and untrained bilinguals. The study showed that interpreting performance was better when second language proficiency was higher after being tested in high-memory spans, reading spans, working memory spans and bilingual controls and after two years of training. The working memory span was higher with students after two years of training than participants that had only trained one year, but the difference was not significant. Thus, differences in interpreting performance and working memory are influenced by different degrees in language proficiency and formal training leads to enhanced language processing skills.

However, there is some research that indicates that interpreters do not perform better than non-interpreters and that they consequently do not have superior cognitive skills. Firstly, Liu, Schallert and Carroll (2004) experimented with individuals with comparable cognitive skills that are different from skills gauged by tasks specifically used for simultaneous interpreting to establish whether there is a difference in performance in simultaneous interpreting (from English into Mandarin). Two groups of student interpreters, one advanced and one group of beginners, were compared to a group of professional interpreters on general working memory capacity, gauged by a listening span task and a reading span task. The level of experience was different for all groups, but they possessed similar cognitive abilities. The entrance requirements for the interpreter training programme they were participating in guaranteed similar language proficiency and academic ability for all three groups. Thus, a larger working memory capacity cannot be the cause of better performances by professional interpreters. Results showed that student interpreters were outperformed by professional interpreters. As professional interpreters had equal general working memory capacity, the difference was partly associated with the improvement on limited cognitive resources of abilities in managing contesting demands (Liu et al., 2004).

Most studies concentrate on working memory storage capacity but research by Timarová et al. (2014) focuses on the central executive functions. They tested 28 professional interpreters on four central executive tasks and three interpretation tasks. Resistance to interference, inhibition, updating and switching were tested with different tasks: resistance to interference was tested with an arrow flanker task and participants had to indicate the direction of a middle arrow that was presented between distracting arrows on each side of the central arrow. The participants had to resist interference from the distracting arrows. Inhibition was gauged by the antisaccade task, which also required the indication of an arrow, but this time it appeared on the left or right of the screen and a distractor appeared on the opposite side of the screen before the arrow that had to be indicated was presented. Participants had to ignore the distractor. A 2-back task was used, which required participants to indicate whether the letter that appeared was similar to the letter that appeared two steps back. Furthermore, a number-letter task was used to gauge shifting. Participants were required to determine whether the number in the presented number-letter pair was even or odd when it appeared in the top of a grid, or whether the letter was a vowel or a consonant when it appeared in the bottom of the grid. The 2-back task and the number-letter task showed a correlation between the interpretation of numbers and those two tasks that measure central executive functions. However, they were the only two tasks that showed a relation between better performance and updating of the memory or switching from one task to another and on top of that, further analysis showed that with the 2-back task, interpreters used less extensive vocabulary to update their memory. According to Timarová et al. (2014), experience in interpreting is related to age because experienced interpreters are mostly older than less experienced colleagues. The arrow flanker task showed better performances, which are related to a general cognitive measure and simultaneous interpreting measures, which led to the belief that interpreting experience is related to the ability to control attention and resist interference of irrelevant distractors. This ability could develop with practice, although automatic response inhibition, updating and attention switching seem not to, despite their reflection of cognitive abilities (Timarová, 2014). Thus, certain measurable aspects of interpreting are related to working memory executive functions.

To our knowledge, Köpke and Nespoulous (2006) were the only others to test executive functions and tested automatic responses inhibition with a Stroop test. Participants had to read aloud or name items as quickly as possible within a certain amount of time. No differences were found between interpreters and non-interpreters in inhibiting automatic responses. Köpke and Nespoulous (2006) also experimented with auditory working memory tasks and phonological and semantic tasks such as short-term retention, short-term retention and processing in a recall task with articulatory suppression, a listening span task and a category and rhyme probe task that required the subjects to listen to lists of 4 to 12 items and at the end of every list, a probe word followed. They had to determine whether one of the words in the list rhymed with the probe word, and whether the probe word belonged to the same semantic category as one of the words in the list. French-English professional interpreters, non-interpreter bilinguals, second year interpretation students and non-interpreter monolinguals of approximately the same age were tested. Almost no differences were found between the expert group and the novices and furthermore, there were similarities between interpreters and non-interpreters. Between-group differences in simple span tasks was not found. Listening span tasks did not show any significant differences between professional interpreters and student interpreters. Semantic tasks showed more significant results in comparison to monolinguals, thus for non-interpreter bilinguals as well, which led to the conclusion that the effect cannot be contributed to interpreter training and that novice or expert interpreters are not more evolved in short-term retention based on the phonological loop than bilinguals or monolinguals.

The abovementioned studies indicate that research to working memory and executive control in relation to interpreting has generated rather contradictory results. There are several possible explanations for the contradictory results. Köpke and Signorelli (2012) researched what may be the causes. A considerable amount of results involving free recall tasks, i.e. while listening to a word list, subjects have to repeat the word ‘bla’, show that interpreters possess cognitive advantages, and only when this task is used. This is not applicable to serial recall, which requires the subjects to recall items in a particular order, and this suggests that experts develop the ability to establish relations between items over the course of time. Thus, everything greatly depends on the tasks that are used. Another important variable is the level of experience. Evidence shows that novice interpreters who are only just starting their careers depend on working memory skills more regularly than professional interpreters (Köpke and Nespoulous, 2006). A third factor is the participant selection, though for research involving reading or listening span tasks this is not that important because participants with very similar profiles were used. Moreover, participant selection can produce contradictory results in complex memory tasks. For example, when experts and novices are compared, they either perform better, which was corroborated by Köpke and Nespoulous (2006) or they do not perform better, as Liu et al. (2004) confirmed. Consequently, the type of training is an important factor. It can consist of one or two years or focus on different aspects, such as shadowing and sight translation or on more specific memory training with exercises such as remembering telephone numbers, and the concerning qualities of later experience can be important as well.

All this research leads to the conclusion that executive functions seem to be related to interpreter training, though no research has been conducted to measure the effect of interpreter training on inhibiting, switching and updating skills. However, research has been conducted in order to test whether switching and inhibiting can be enhanced with experience (Timarová et al., 2014). Interpreter training and experience in interpreting are two different concepts, as one does not necessarily imply the other. Experience and skill could further develop after training, for instance. The effect of training executive control functions was measured by Karbach and Kray (2009) and by Kray, Karbach, Haenig and Freitag (2012) in a different context than interpreting, but confirms that training could be a factor of enhanced executive control. The current study will take into account some of the aforementioned limitations stated by Köpke and Signorelli (2012) and also consider the fact that the same and quite limited group of participants was tested before and after training. In the following section, we will elaborate on how we operated and explain the tasks that were used to measure whether interpreter training and executive control are related.

3. METHODOLOGY

In this section, we will elaborate on the participants, the procedure and materials used in this research. The aim of this study is to establish whether a year of interpreter training enhances the working memory executive control of interpreting students. In order to establish whether this is in fact the case, fifteen interpreter graduates were tested. In the fall of 2014, a study was performed by Rosiers et al. (submitted) (see section 1) among students that were, at the time, taking a Master in interpretation, a Master in communication and a Master in translation. Of those students, sixteen were training to be an interpreter. These students' results will be used in the current research.

In Rosiers et al.'s study, all students were asked to perform four executive control tasks testing either switching, updating or inhibiting skills and one working memory capacity task, which tests storage capacity. Because executive control is widely accepted to consist of those components (Miyake et al., 2000), the tasks that test them are imperative to this research and to establish whether interpreter training enhances working memory executive control. Therefore, this year, after completing their training in interpreting and thus having graduated, the students were asked to perform the tasks once more. Participants were tested again in October and November of the academic year 2015-2016 not long after graduation to eliminate potential changes in working memory and executive control either caused by increased or decreased interpreter practice as some students might be working as professional interpreters and others may not.

3.1 <u>Participants</u>

As this study relies on previous research, the number of participants was determined by the design of that research. Only sixteen interpretation students were tested by Rosiers et al. (submitted), therefore only those sixteen could be contacted. In order to convince them to take part in this follow-up study involving the same tests, they were offered a €25 gift certificate from multimedia store Fnac, funded by the University of Ghent. Via e-mail and Facebook, they were contacted and asked for their cooperation. As they had done the same tasks already one year before, they knew how long it would take, which was about three quarters of an hour up to one hour. Out of a total of sixteen students available through last year's study, we were able to persuade fifteen to take part for a second time. Considering we had no other participants to fall back on, this is a successful outcome. However, the participants were (mostly) no longer studying in Ghent as they had graduated the previous year. The participants had the opportunity to choose the time and location of the test, partly in an attempt to persuade them to take part. Agreeing on a time and place was, however, no easy task and obviously involved a great deal of planning and travelling.

Two participants are currently enrolled in the post-graduate conference interpreting programme. Three other participants are taking the specific teacher's training (SLO) programme while all other subjects are pursuing careers that are not related to interpreting. The subjects were tested in the fall of 2015 after they had graduated either in July or in September. This particular timing was chosen to assure that all participants from the first study had in fact graduated as Masters in interpreting but had not yet gained additional interpreter experience through a first job or through the postgraduate programme.

3.2 Material

Four computer-based tasks and one oral digit span task were used to test the participants. Regardless of the fact that they had already executed all tasks once before, they were explained everything anew in their mother tongue (i.e. Dutch). On the computer screen an explanation appeared as well, describing what they had to do.

The tasks were counterbalanced, which means that every participant executed the tasks in a different order. This way we avoided that one particular task was considered more strenuous due to fatigue, which could have made the data unreliable. In what follows, all tasks will be explained as to how they work and what they test, starting with the digit span and continuing with the 2-back task, the switch task, the Simon task and ending with the ANT.

3.2.1 Digit Span

The digit span is a test adapted from the third edition of Wechsler's Adult Intelligence Scale, which consists of three tasks: solving sums (counting), remembering a number of digits in same or reversed order (digit span) and rearranging a number of digits and characters (repeating digits and characters) (Aben, 2013). In order to assess working memory, this test is often used and is therefore imperial to this study. The participants are asked to recall and repeat the digits read to them in the same order. The smallest sequence consisted of two digits and kept being added up to until the longest of nine digits. There exist two sequences of the same length in order to have a second chance when failing the first one and in total, sixteen sequences in are read to the participant normal order until a mistake is made at the end of a sequence. Afterwards, the participants were read another series of digits; only, this time, the participants had to recall and repeat the digits in reverse order. Again, the length varied from two to nine digits (Rosiers et al, submitted). However, only fourteen sequences were implemented here, as this backward task is significantly more difficult than normal order repetition and as the task is more strenuous because the data has to be manipulated, it does not merely test storage capacity but also executive control.

3.2.2 2-back task

The 2-back task measures the updating function, which implies that participants have to compare new incoming information to information they already possess in their memory (Rosiers et al., submitted). In the 2-back task, 25 black and white drawings were included. According to a norming study by Severens, Lommel, Ratinckx, and Hartsuiker (2005) those drawings provided high naming agreement in Dutch and agreement was above 74% for all pictures. For each picture, the dominant name was determined, which is the name that was most used by the participants, and these names turned out to all be monosyllabic ones. For this task, two blocks of 94 trials each with a pause halfway through were presented to the participants but the first two trials of each block did not require a response so that the blocks would consist of 90 trials each to be analysed. Thirty match trials, which means that the picture was identical to the picture presented two positions before and sixty mismatch trials, where the picture was not identical to the picture shown two before, made up the first block. The second block then consisted of 13 n+1 lure trials, which means that the picture matches the picture three items back, 30 match trials and 47 mismatch trials. In this way the amount of ‘yes’ and ‘no’ responses were evenly balanced (Rosiers et al, submitted). Through counterbalancing, the matches, mismatches and lure trials appeared in different orders on screen for each participant. The task started with 47 practice trials before the experiment started and did not contain any lure trials, though the participants were never even aware of the existence of said lure trials, not in the practice block, nor in the real experiment. During the task, the drawings appeared one by one on the computer screen and remained there for 2000 ms. Afterwards, a blank screen followed for 1000 ms long and subsequently, participants had to respond as fast and accurate as possible by pressing the right key when the image was indeed a match and by pressing the left key with mismatches on the keyboard. Via E-Prime, stimulus presentation software (Schneider, Eschman & Zuccolotto, 2002), stimuli were presented on an IBM-compatible laptop computer running windows xp (Rosiers et al, submitted).

3.2.3 Switch task

The colour-shape switch task gauges the shifting or switching function which consisted of two blocked conditions, a colour block condition and a shape block condition, and a switch condition. During the colour block condition, participants had to look at the colour of an image while during the shape block condition participants needed to look at the shape of the image that appeared on screen. The switch condition, on the other hand, required the participants to switch between colour and shape (Rosiers et al., submitted). The switch cost is the effect of having to switch from shape to colour or vice versa and is calculated by deducting the switch trial scores from the stay trial scores. In the switch condition, a cue appeared on screen in order to inform the participants about which condition they had to respond to, so a multi-coloured circle appeared for colour or a white octagram appeared to predict shape. Blue or yellow triangles and squares appeared on screen for 2500 ms, unless an earlier response was given and were followed by 300 ms intervals. In the switch condition, a 400 ms cue was given before the stimulus after the fixation. When participant had to look only at coloured images, they had to press the left key when a yellow image appeared and the left key when a blue image appeared. During the shape condition, they had to press left again when a triangle appeared and right when a square appeared, whereas the switch condition combined these two tasks. The latter condition consisted of two blocks of 47 trials and each contained 20 switch trials, while the former consisted of 8 practice trials and 34 experimental trials. There was always a practice phase preceding the actual task. Anew, counterbalancing provided a more substantial result and stimuli were presented via E-Prime (Rosiers et al., submitted).

3.2.4 Simon task

The first obtained Simon effect dates from 1969 when Simon and Small experimented with auditory stimuli and they proved that people respond faster to a command they have to execute with a key on the right when they hear it in their right ear rather than through the left ear. Simon and Small (1969) attributed this occurrence to a natural tendency to react towards the stimulation source and that it is more difficult to ignore that tendency and therefore inhibit. The Simon effect is the increased time that is needed to counter the incongruent items. Thus, in order to test a first executive control function called inhibition, the Simon task was used. The Simon task is a colour-related task and required the participant to respond to coloured objects. The task works as follows: firstly, a green or red coloured object appears on the left or right side of the screen and when the dot is green, the participants are asked to press the left key and when the dot is red the right key as correctly and fast as possible (this was reversed according to the participant number). Position and colour extracted the same reaction and are called congruent trials, or they extract different reactions, which are called incongruent trials (Rosiers et al., submitted). An incongruent trial, for example, is one that requires inhibitory skills and congruent trials make no use of executive control and are therefore less challenging. Participants had to run through 10 arbitrary practice trials and 100 experimental trials, of which half appeared left on screen and the other half on the right (Rosiers et al., submitted). Tscope software provided the necessary stimuli, “a programming library designed for programming experiments that run on Windows XP” (Stevens, Lammertyn, Verbruggen, & Vandierendonck, 2006, p. 280). The software was used on an IBM-compatible laptop computer and is particularly designed for experimental psychologists with moderate abilities in programming (Stevens et al., 2006).

3.2.5 ANT

ANT or Attention Network Test is another task that is used to measure the executive network, namely the inhibition function, and the orienting network. Although the task is slightly different than the Simon task, it also tests a type of inhibition, but in this case the resistance to interference. The participants had to indicate the direction of the middle arrow, which pointed to the left or to the right, in a series of five arrows by pressing the right or left key. Two within-subject factors were involved in this task. The first one is the flanker type, which are congruent and incongruent trials, and the second one is the cue type, which gauges the orienting skills. The cues were either indicated in the identical location as the fixation, thus in the centre, or at the location where the approaching target would appear (spatial cues), or no cue could appear at all. For the purpose of this study, we examined the participants' executive network, which was gauged by a comparison between the congruent and incongruent trials and did not investigate the participants orienting network (Rosiers et al., submitted). One session contained a 6-trial demo block, a 12-trial full feedback practice block, and three experimental blocks of 48 randomised trials. The conditions were each shown equally as long and each trial consisted of a fixation that could last between 400-1600 ms, a cue for 100 ms, a second fixation but now of a fixed 400 ms, a target arrow and congruent and incongruent trials above or below fixation could last up to 1700 ms unless an earlier response was given. No 100 ms cue or second fixation existed in the no cue condition. Participants were required to answer as accurately and quickly as possible with the right key when the target pointed to the right and with the left key when the target pointed to the left. Stimuli were presented via E-Prime on an IBM-compatible laptop computer with a 15-inch screen, running XP (Rosiers et al, submitted).

In what follows, the data will be provided of both test phases, thus before and after interpreting training. Accuracy and swiftness are the two significant factors that were analysed in order to compare them to the previous study.

4. RESULTS

To compare one group at two different moments, a paired samples T-test is used, which is a statistical technique used to compare correlated samples (statistics solutions, 2006). It is often used in 'before-after' studies, and as our experiment has a within-subject design, which means that the same participants were tested before and after a type of treatment, this test was used to statistically measure the significance of our results and to establish whether our group of subjects had improved significantly after training in comparison with before. Data were analysed using SPSS, version 23.

In the following section, we will discuss the results on each executive control task separately, starting with the digit span and continuing with the 2-back task, the switch task, the Simon task and the ANT. Afterwards, we will elaborate on these results in the discussion and formulate answers to the corresponding research questions.

Tables 1 to 5 present a summary of the measures that were used to tap the executive functions. T1 represents the participant group's results at the first test point, before they started interpreting training, and T2 represents the same group's results one year later, when they had finished their training. In Tables 2 to 5, the results of the executive control tasks are expressed either in mean reaction time (RT) or in accuracy rate (ACC).

4.1 Digit Span task

	T1		**T2**	
	M	**SD**	**M**	**SD**
Span forward	9,86	2,11	10,93	1,78
Span backward	7,36	1,87	9,00	2,42
Span total	17,21	3,53	19,86	4,04
Span effect	2,50	1,83	1,93	1,33

Table 1: Mean scores (M) and standard deviations (SD) for the digit span task

Table 1 shows the mean group differences in performance on the forward span and the backward span on average. The span effect is the difference between the forward and backward span and shows how much effort the participants experienced as a result of the more difficult backward condition. A paired samples t-test was conducted to compare the results between the forward spans, the backward spans, the total spans and the span effects. There was a significant difference in the scores for the backward span between T1 (M= 7.36, SD= 1.87) and T2 (M= 9.00, SD= 2.42); t(13)= -3.371, p= 0.005 and for the total span from T1 (M= 17.21, D= 3.53) to T2 (M= 19.86, SD= 4.04); t(13)= -2.96, p= 0.011, both with a higher score on T2 than on T1. This trend is also noticeable in the forward span scores, although it was not statistically significant for T1 (M= 9.86, SD= 2.11) and T2 (M= 10.93, SD= 1.77); t(13)= -2.066, p= 0.059. The same trend is observed in the span effect. Despite the lack of a significant result for T1 (M= 2.50, SD= 1.83) to T2 (M= 1.93, SD= 1.33); t(13)= 1.170, p= 0.263, the span effect has become smaller in the second trial, meaning that the participants needed less effort to complete the tasks the second time around. Overall, participants seem to have improved both their storage capacity and their executive control skills, as measured by the digit span.

4.2 2-back task

	T1		**T2**	
	M	**SD**	**M**	**SD**
Match RT	762,71	170,48	665,55	150,59
Mismatch RT	710,01	108,49	613,70	90,89
Lure	893,39	220,16	786,63	141,19
Match ACC	98,94	1,11	98,82	1,56
Mismatch ACC	84,67	9,20	87,44	8,73
Lure ACC	69,23	17,92	71,28	14,38

Table 2: Mean scores (M) and standard deviations (SD) for the 2-back task

Table 2 contains the RT and ACC rates on the 2-back task. These results are divided into three conditions: match, mismatch and lure. A match trial indicates that the image on screen was the same as two images before that, as opposed to a mismatch trial, which means that they were different images. Lure trials indicate that the image on screen was not the same as two positions earlier, but was the same as three images before. The mean reaction time indicate that the participants improved on all levels and that they could identify the right or wrong image quicker than in the first test phase. This improvement was found to be significant for the reaction times in match trials from T1 (M= 762.71, SD= 170.48) to T2 (M= 665.55, SD= 150.59); t(14)= 3.07, p= 0.008, mismatch trials for T1 (M= 710.01, SD= 108.49) and T2 (M= 613.70, SD= 90.89); t(14)= 3.53, p= 0.003 and lure trials for T1 (M= 893.39, SD= 220.16) and T2 (M= 785.63, SD= 141.19); t(14)= 2.47, p= 0.027. Regarding accuracy scores, the participants were slightly more accurate in the mismatch trials and the lure trials at T2. This was not the case for the accuracy rate on the match trials, which remained stable. This might be caused by the high initial accuracy rate (98.9%). None of these changes in accuracy scores were significant for match trials for T1 (M= 98.94, SD= 1.11) and T2 (M= 98.82, SD= 1.56); t(14)= 0.254, p= 0.803, mismatch trials for T1 (M= 84.67, SD= 9.20) and T2 (M= 87.44, SD= 8.73); t(14)= -1.51, p= 0.153 and lure trials for T1 (M=69.23, SD= 17.92) and T2 (M= 71.28, SD= 14.38); t(14)= -0.401, p= 0.695.

4.3 Switch task

	T1		**T2**	
	M	**SD**	**M**	**SD**
Mono RT	410,13	51,24	381,91	80,28
Stay RT	616,67	142,38	510,79	115,59
Switch RT	759,73	177,33	655,43	206,51
Mono ACC	98,41	1,90	97,96	2,22
Stay ACC	90,44	12,74	95,89	2,51
Switch ACC	87,83	11,80	92,00	6,90
Switch cost RT	143,07	128,60	144,64	111,41
Switch cost ACC	-2,61	4,98	-3,89	5,76
Mix Cost RT	206,53	153,48	128,89	89,36
Mix Cost ACC	-7,97	13,30	-2,07	2,59

Table 3: Mean scores (M) and standard deviations (SD) for the switch task

Table 3 illustrates the mean RT and ACC for three conditions in the switch task. Firstly, the mono condition was tested, which is the phase in which the participants had to deal with blocked conditions and they could only expect colour or geometrical designs. Secondly, a distinction was made in the switch condition between stay trials and switch trials. The former indicates that the participant did not have to switch and that the first as well as the next item required attention to colour, for instance, and the latter indicates that the participants did have to switch tasks between colour and shape. Finally, the mix cost, which is attained by subtracting the mono condition scores from the stay trials in the switch condition, and switch cost are given for both RT and ACC. The reaction times indicate improvement in all three conditions, however for the mono condition this was not significant for T1 (M= 410.13, SD= 51.24) and T2 (M= 381.91, SD= 80.28); t(14)= 1.54, p= 0.145 and not significant for the switch condition from T1 (M=759.73 , SD= 177.33) to T2 (M= 655.43, SD= 206.51); t(14)= 1.63, p= 0.126. A significant difference was found between the reaction times on the stay trials at T1 (M= 616.67, SD= 142.38) and T2 (M= 510.79, SD= 115.59), t(14)= 2.39, p= 0.032. For reaction time, another significant result was discovered for the mix cost for T1 (M= 206.53, SD= 153.48) and T2 (M= 128.89, SD= 89.36); t(14)= 2.18, p= 0.047 but not for the switch cost for T1 (M= 143.07, SD= 128.60) to T2 (M=144.64 , SD= 111.41); t(14)= -0.4, p= 0.969. For accuracy, the participants did slightly better on all but the mono condition, which slightly deteriorated for T1 (M= 98.41, SD= 1.90) and T2 (M= 97.97, SD= 2.22) conditions; t(14)= 0.579, p= 0.572. For accuracy, no significance was found for stay trials from T1 (M= 90.44, SD= 12.74) to T2 (M= 95.89, SD= 2.51); t(14)= -1.81, p= 0.092 and switch trials from T1 (M= 87.83, SD= 11.80) to T2 (M= 92.00, SD= 6.90); t(14)= -1.174, p= 0.260. The mix cost for T1 (M= -7.97, SD= 13.30) and T2 (M= -2.07, SD= 2.58); t(14)= -1.83, p= 0.088 and switch cost for T1 (M= -2.61, SD= 4.98) and T2 (M= -3.89, SD= 5.76); t(14)= 0.59, p= 0.566 increased, which indicates that the effect of having to switch was less strenuous. No significant improvement for accuracy was obtained.

4.4 Simon task

	T1		**T2**	
	M	**SD**	**M**	**SD**
RT congruent	372,75	46,57	363,34	67,85
RT incongruent	405,89	47,56	390,90	67,73
RT Effect	33,13	10,80	27,56	12,17
ACC congruent	96,64	2,27	97,79	1,72
ACC incongruent	92,79	5,34	93,64	4,29
ACC Effect	-3,60	4,61	-3,87	3,70

Table 4: Mean scores (M) and standard deviations (SD) for the Simon task

As mentioned in section 3, in the Simon task a distinction is made between congruent and incongruent trials. The incongruent trial requires inhibitory skills as the participant needs to resist an automatic reflex induced by the location of the coloured dot. Therefore this condition is the more challenging one, which generally results in slower and less accurate responses than for the congruent trials. Table 4 displays the mean reaction times (RT) in milliseconds and the mean accuracy rates (ACC) as a percentage for the congruent and incongruent trials as well as the Simon effect. These figures reveal that the difference in reaction time and accuracy at T1 and T2 is negligible and lacks statistical significance. With regard to the accuracy rates, we should note that the participants already obtained fairly high scores at T1 (between 92.8% and 97.8%), which left little room for improvement. The Simon effect – the impact of the inhibition task – is somewhat smaller at T2 compared to T1. Yet, this difference is not significant between T1 (M= 33.13, SD= 10.81) and T2 (M= 27.56, SD= 12.17); t(13)= 1.62, p= 0.130. For accuracy however, there was a significant difference in the congruent trials between T1 (M= 96.64, SD= 2.27) and T2 (M= 97.79, SD= 1.72); t(13)= -2.45, p= 0.029, but not in the incongruent trials from T1 (M= 92.79, SD= 5.34) to T2 (M= 93.64, SD= 4.29); t(13)= -0.513 p= 0.616. Finally, the Simon effect in terms of accuracy did not show a significant change from T1 (M= -3.60, SD= 4.61) to T2 (M= -3.87, SD= 3.70); t(13)= 0.193, p= 0.849.

4.5 ANT

	T1		**T2**	
	M	**SD**	**M**	**SD**
RT congruent	486,40	67,50	483,67	65,01
RT incongruent	578,23	82,18	556,71	69,91
Effect RT	91,83	29,29	73,04	18,61
ACC congruent	99,54	0,68	99,72	0,78
ACC incongruent	93,52	7,11	95,28	5,75
Effect ACC	-6,02	7,11	-4,44	5,80

Table 5: Mean scores (M) and standard deviations (SD) for the ANT

Table 5 shows the mean RT and ACC for congruent and incongruent trials. A congruent trial occurs when all the arrows surrounding the middle arrow point in the same direction while an incongruent trial indicates that the arrows surrounding the middle one point to a different direction than the middle one. The mean RT on the congruent trials demonstrate no apparent change from T1 (M= 486.40, SD= 67.50) to T2 (M= 483.67, SD= 65.01); t(14)= 0.442, p= 0.665, while the incongruent trials do show a significant improvement for T1 (M= 578.23, SD= 82.18) and T2 (M= 556.71, SD= 69.91), t(14)= 2.54, p= 0.024. The effect of the incongruent condition is significant for reaction time for T1 (M= 91.83, SD= 29.29) to T2 (M= 73.04, SD= 18.61), t(14)= 3.62, p= 0.003. The accuracy rates for all conditions show no significant change for congruent trials from T1 (M= 99.54, SD= .68) to T2 (M= 99.72, SD= .78); t(14)= -0.81, p= 0.433, incongruent trials from T1 (M= 93.52, SD= 7.11) to T2 (M= 95.28, SD= 5.75); t(14)= -1.40, p= 0.182 and the effect of the incongruent condition for accuracy from T1 (M= -6.02, SD= 7.11) to T2 (M= -4.44, SD= 5.80); t(14)= -1.26, p= 0.228.

5. DISCUSSION

The primary aim of this study was to investigate the influence of interpreter training on executive control. At first glance, interpreter training seems to have an effect on overall results, but little significance was found for all tasks. Therefore, this section will discuss each research question and try and explain contradicting results.

5.1 Do the interpreters exhibit significant improvement in storage capacity?

An interesting finding is that results were significant for the backward span, which is the component of the digit span task that is the most important to our research, as there is cognitive control involved in this particular assignment. This indicates that after interpreting training, students are better at manipulating information (in this case, retaining sequences of digits and repeating them in the opposite order). Although the difference in span effect between T1 and T2 was not significant, the tendencies show improved results, which indicates that participants had less trouble with the changed condition. Overall improvement on the forward and the backward span can be attributed to extensive memory training during the Master in interpretation. Initial steps of training in interpretation often consist of exercises that train the memory. For instance, remembering telephone numbers and retelling a story without being able to take notes are commonly used exercises.

5.2 Do the interpreters exhibit significant improvement in updating skills?

The 2-back task shows that after interpreter training students are better at remembering and identifying images that were shown to them in challenging circumstances. On top of that, they significantly improved on speed. They were better at identifying images that appeared two images before that, which was a distractor implemented to deceive the participants. It indicates that participant did remember the image, but they had to be certain that it resembled with the second image shown after and not with the preceding or following one. Although the accuracy rate did not change significantly, there is a clear trend towards improvement in the mismatch and lure trials. The fact that the accuracy rate remained stable for match trials might be caused by the initial high accuracy rate (98.94%). Even despite the lack of significance for the accuracy rates, it cannot go unnoticed that the interpreters became faster in this particular task and that this improved speed did not have a detrimental effect on the accuracy rates in the task. A possible explanation for this improved performance might be found in the fact that interpreters constantly have to retain incoming information and process it at the same time while interpreting (Timarová et al., 2014). During training, they will have had to do this in simulations of interpreting exercises which could be a possible explanation for improvement of updating skills.

5.3 Do the interpreters exhibit significant improvement in switching skills?

There is a pronounced trend of improvement from T1 to T2, both in terms of speed and accuracy. However, this improvement is only significant for the condition that does not require participants to switch, i.e. the stay trials. Another important finding was a significant improvement for the mix cost, which means that participant were better at switching while facing more difficult conditions. An explanation for the insignificant results could also be a consequence of the notion of having to switch. This could have reacted in slower reaction times, because participants expected that they would have to switch, but did not always have to. However, according to Karbach and Kray (2009), training could improve executive functions, which they tested for the switch task. Their study was unrelated to interpreting, but they showed that when their subject had access to training tasks, they performed better afterwards. It can therefore be assumed that practicing switching during interpreter training also leads to better performances. On top of that, exercises that are used in the training programme are beneficial for switching skills. Those skills are trained with exercises as having to interpret simultaneously and solve (simple) math sums at the same time.

5.4 Do the interpreters exhibit significant improvement in inhibition skills?

5.4.1 Simon task

Tendencies show that the participants have improved upon accuracy and reaction time, which could lead to the conclusion that they struggled less in more difficult conditions. All scores have improved in comparison with last year's scores, but that improvement is rather minimal (see table 4, section 4). It could be argued that the negative results were due to the ceiling effect and that the participants could not improve much, but this is not valid for all tested conditions. The type of inhibition tested with this task, e.g. response inhibition, could be the cause of insignificant results. According to Bialystok, Craik and Klein and Viswanathan (2004), advantages for bilinguals are not discovered in all types of inhibition. For instance, response inhibition (tested with the Simon task) and interference suppression (tested with the ANT) are very distinctive. Response inhibition implies a dominant response correlated with a univalent stimulus that has to be overruled, while interference suppression consists of a bivalent stimulus with two cues where attention must be focused on the relevant cue. In the Simon task, the participants are not aware of the nature of interfering information until it appears on the display. On top of that, a distinction between global an local inhibition was made (Bialystok, Craik & Luk, 2012). Local inhibition is the inhibition of a specific competing distractor and affects linguistic performance. Global inhibition relates to the suppression of a language system in its entirety and affects linguistic and cognitive performance (Bialystok et al., 2012). This difference in types of inhibition is a possible explanation for insignificant results in the Simon task. However, this task showed significant results for accuracy in the congruent trials. This condition is less important for our research because it is an indicator of the ability to identify the correct in normal conditions, for instance when the image appears on the right side and you have to use the right side key.

5.4.2 ANT

Incongruent trials show significant results with the ANT task for reaction time, hence they have improved on speed when they face harder conditions. In the incongruent trials, the arrows pointed in a different direction than the middle arrow, which means that the participants had to inhibit these distractors. Bialystok et al. (2012) determined that bilinguals are able to deal with interference more efficiently than monolinguals and are proficient in maintaining relevant tasks in working memory, so this might partly explain the obtained results. On accuracy there are no significant results but tendencies again show an improvement, even though there was little space for improvement (i.e. the ceiling effect). Scores were already quite high in the first test phase, but after test phase two, enhancement can be observed. The subjects resisted to interference and ignored natural inclinations.

Overall, we could say that interpreters improved on all executive control functions but that they did not show significant improvement on all tasks. The lack of significant differences could be due to the small sample of participants. In this study only fifteen interpreters were tested, which is a very limited amount, but only a small amount of students enrol in the Master in interpretation of Ghent. Therefore, future research could test more participants, but this would not necessarily lead to more significant results.

Other factors such as the type of training could be of great influence. A considerable amount of interpreting studies (mostly abroad) take one to two years while in Belgium, training takes mostly one single year. Two years of training leads to more specific training and thus, probably, more elaborate skill development. During the Master in interpretation in Ghent, the focus does lie on memory training, but a year is a short amount of time. However, the participants tested in this study showed improvement on almost all tasks. Moreover, according to Timarová (2014), executive functions could be related to experience and therefore develop over the years when interpreters gain more expertise and skill. The level of experience was claimed to be an important factor by Köpke and Nespoulous (2006) and that novice interpreters depend more on working memory skills. As our test subjects were only recently graduated, their improvements could be correlated with working memory skills.

Moreover, Miyake et al. (2000) discussed the issue of task impurity and stated that no task purely measures inhibition or updating, and that other processes are involved as well. Low scores or insignificant scores are therefore not always due to inadequate inhibition skills, thus this could also be a factor in explaining our insignificant results. Executive tasks involve other cognitive processes indirectly relevant to the target executive function because executive functions reveal themselves by operating on other cognitive processes. Therefore, one single executive test that shows a lower score does not imply “inefficient or impaired executive functioning” (p. 53). On top of that, Miyake et al. (2000) described another problem in relation to the reliance on executive tasks. Complex executive tasks that are used to gauge executive functions are widely accepted but their “construct validities” (p. 53) are not authenticated. The nature of executive processes that are implied in these tasks’ performances is not specified sufficiently and insufficient evidence has been found to their nature and what they actually measure.

6. CONCLUSION

This study aimed to investigate whether interpreter training has any influence on working memory executive control. Only few studies discussed interpreter training and looked into the relation between interpreter training and working memory or executive control. Studies such as Darò & Fabbro (1994), Christoffels et al. (2006), Signorelli (2008), Karbach and Kray (2009) and Tzou et al. (2011) did show that there is a relation between interpreters and enhanced working memory or executive control abilities. However, this study found a relation with interpreter training as well. Before training, interpreter students did not possess superior working memory and executive control abilities, as was confirmed in Rosiers et al. (submitted). The interpreter students were compared with other language students by Rosiers et al. (submitted), but now with a within-subject design, storage capacity and three executive functions were gauged again by means of the digit span task, the 2-back task, the switch task, the Simon task and ANT.

Fifteen interpreters were tested a second time after they graduated in a Master in interpretation. Results showed significant results for accuracy in congruent trials for the Simon task, for reaction time in incongruent trials and the ANT-effect for ANT. For the switch task, the stay trials for reaction time were significant and for the 2-back task, match, mismatch and lure trials for reaction time were significant. However, tendencies show improvement on all tasks and subtasks; except for match trials in the 2-back task for accuracy, which remained stable.

Interpreters exhibit more enhanced executive control abilities after interpreter training than before they started the training and although not all functions that were tested were as equally strong, interpreter training does seem to have an effect on working memory executive control.

Future research could be undertaken to test the differences in interpreter training in different institutions. A favourable outcome was obtained for interpreters that had enrolled in the Master in interpretation in Ghent, and it would be interesting to investigate whether other institutions use the same exercises and training and show the same results. It would be interesting to investigate and compare the Master in Ghent with an institution that has a Master's programme that consists of two years. If one year of training already shows remarkable results, two years could lead to even better performances and better executive control abilities. If more significant results are obtained after two years of training, this could be of importance for a potential reform of the Master programme of one year. Tzou et al. (2011) already determined that working memory span was higher after two years of training, in comparison to interpreters that only had one year of training, thus it would be interesting to investigate whether this would be the case for executive control functions.

Furthermore, the current study could be used in a comparative study with more experienced interpreters to test whether they evolve even more with practice and experience after their training. Practice and training being two different concepts, it would be an interesting course of action because Timarová (2014) determined that experience shows enhanced executive control abilities. However, a comparative study between practice and training could show more conclusively which one is related more to executive control enhancements, or whether they are equally important.

Future research could also investigate the nature and construct of tasks that are used to gauge working memory executive control. Miyake et al. (2000) already argued the task impurity and for this study, this could have played an important part in obtaining the results. On top of that, because a task does not necessarily gauge one executive function, determining faults and constructing new (or perfecting existing) tasks to measure a certain executive function more accurately, could lead to better results.

By way of conclusion, we can say that interpreter training has an effect on the executive control functions inhibition, updating and switching and that the content of the Master in interpretation in Ghent is advantageous for training executive functions. Because of the satisfying results obtained, this study is valuable for future research in interpreter studies in relation with working memory and executive control and can serve as a foundation for research on a greater scale.

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