Working Memory and Simultaneous Interpreting

Šárka TIMAROVÁ

Charles University, Prague / Lessius University College, Antwerp

Abstract

The paper presents a theoretical overview of the concept of working memory and its application in interpreting research. Three representative models of working memory, as developed in cognitive psychology, are discussed and compared. Three selected models of the interpreting process illustrate the theoretical approaches to modelling the role of working memory in (simultaneous) interpreting. Three selected types of studies illustrate empirical approaches to researching the role of working memory in interpreting. Finally, suggestions are made for future research to investigate more working memory functions and to relate them more directly to the interpreting process.

1. Introduction[1]

The concept of working memory was proposed in the 1970s by Baddeley and Hitch (1974) as a modification of the concept of short-term memory. The crucial difference was that short-term memory was a simple store for information, while the more modern concept of working memory is assumed to be a cognitive component combining storage, processing and executive control of the cognitive processes at hand. Working memory is one of the most prominent topics in both current cognitive research and interpreting research. With more empirical findings available, working memory is now linked to a large number of higher-cognitive abilities and processes, and also to intelligence. In interpreting, it is considered to be one of the cognitive cornerstones underlying simultaneous interpreting (SI; Darò, 1989; Bajo, Padilla and Padilla, 2000). A number of studies focused on showing this by demonstrating a difference in working memory between simultaneous interpreters and SI students or non-interpreters. However, the results are mixed: some studies have found a difference (e.g. Padilla, Bajo, Cañas and Padilla, 1995; Christoffels,

[1] Sections 1 and 2 are adopted from Timarová, Š. (2007)

© 2008. Pieter BOULOGNE (ed.). *Translation and Its Others. Selected Papers of the CETRA Research Seminar in Translation Studies 2007*. http://www.kuleuven.be/cetra/papers/papers.html

2004), others have not (e.g. Chincotta and Underwood, 1998; Nordet and Voegtlin, 1998; Köpke and Nespoulous, 2006).

The purpose of this paper is to briefly review theoretical and empirical work about working memory and simultaneous interpreting. In Section 2, a short overview of the present theoretical debate and of findings from cognitive disciplines is presented. In Section 3, we briefly discuss the role of working memory in simultaneous interpreting as reflected in SI process models, and review basic approaches to studying working memory in the context of SI empirically. Finally, Section 4 attempts to integrate conclusions from the previous sections and proposes a new approach to the study of the relationship between working memory and simultaneous interpreting.

2. Working memory

2.1. The Nature of Working Memory

Peter gets two apples from his mother every day, but eats only one. How many apples does he have at the end of the third day? This classic example of mental arithmetic is a good illustration of what working memory is for. To solve the problem, we need to make some stepwise calculations and store the result of each step in order to integrate it with the result of the next step. This type of memory required for the short-term storage of information was first described by William James (1890) as *primary memory*. Research in the 1950s and 1960s showed that the store has a severely limited capacity. The seminal article by Miller (1956) claims humans can at any one time remember a maximum of seven, plus or minus two, chunks. However, the simple storage account did not adequately explain a range of empirical data. This led to the proposal of *working memory*, which combined storage with ongoing processing (Atkinson and Shiffrin, 1971; Baddeley and Hitch, 1974). The concept of working memory in this form has become one of the key constructs in modern cognitive disciplines and through empirical research has been linked to a host of everyday activities, mental abilities and higher-cognitive processes. Working memory is thus known to be related to reading comprehension (Daneman and Carpenter, 1980), language comprehension (Just and Carpenter, 1992), reasoning (Kyllonen and Christal, 1990), vocabulary learning (Baddeley, Gathercole and Papagno,1998), problem solving (Kyllonen and Christal, 1990), or taking lecture notes (Kiewra and Benton, 1988). There is also a growing body of evidence that working memory is strongly related to general intelligence (Engle, Tuholski, Laughlin, and Conway, 1999; Conway, Cowan, Bunting, Therriault and Minkoff, 2002; Redick and Engle, 2006; Jarrold and Towse, 2006). Quite naturally, the huge amount of data collected gave rise to the proposal of numerous theoretical models.

2.2. Conceptualising Working Memory: Models

Since the 1970s, at least a dozen theoretical models have been developed to account for all the findings. In this section, we will focus on only three of them. The selection has been guided by several factors: the model should be representative of the cognitive research, it should be current and updated, and it should provide theoretical background for our discussion of working memory research as it relates to the interpreting process. For this reason, the models briefly discussed in this section will be the multicomponent model by Baddeley (Baddeley and Hitch, 1974; Baddeley, 1996; Baddeley, 2000; Repovš and Baddeley, 2006); the long-term working memory model by Ericsson and Kintsch (1995); and the long-term memory activation model by Cowan (Cowan, 1988, 1995; Oberauer, 2002), and its control-of-attention extension by Conway and Engle (Conway and Engle, 1994; Engle, Tuholski, Laughlin and Conway, 1999; Feldman Barrett, Tugade and Engle, 2004).

2.2.1. Baddeley: A Multicomponent Model

One of the most influential working memory models to date was developed by Alan Baddeley (Baddeley and Hitch, 1974; Baddeley, 1996; Baddeley, 2000). Based on a wide range of empirical findings, this model posits that working memory is composed of separate storage and processing systems. The current version of the model is below in Figure 1.

The model assumes that working memory is composed of two domain-specific slave storage systems - the *phonological loop* and the *visuospatial sketchpad*, a general storage component - the *episodic buffer*, and a supervisory component - the *executive control*. Each of the two slave systems is responsible for temporary storage of domain-specific information, i.e. the phonological loop stores verbal and numerical information, the visuospatial sketchpad specialises in the storage of visual and spatial information. Each slave system is further fractionated into subcomponents.[2] The phonological loop is thus composed of a phonological store and an articulatory control process. The phonological store allows for direct access to auditorily presented verbal information, while visually presented text must first be subvocally articulated by the articulatory control process before it can be stored in the phonological store.

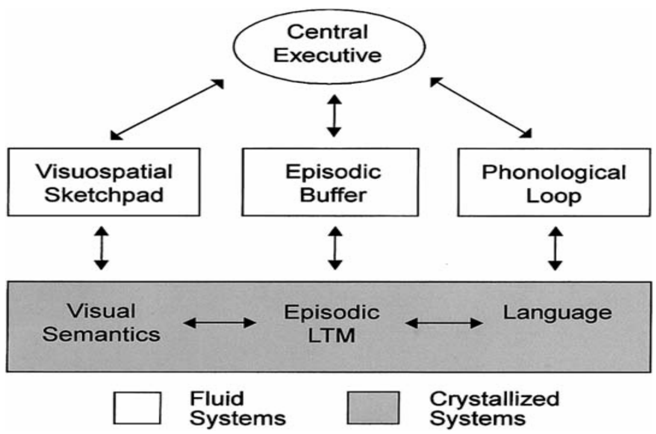

Figure 1.The multicomponent working memory model (From Baddeley, 2000)

Capacity of the working memory is defined as a temporal limitation on the amount of information that can be stored. Empirical findings by Baddeley et al. (1975) have shown that the size of the phonological store is approximately 2 seconds of verbal material, i.e. people can remember as many words as they are able to pronounce in two seconds. The two slave systems are dependent on a central executive, a supervisory component which controls and coordinates mental operations (Hitch, 2005).

Most research has been devoted to exploring the phonological loop (Baddeley, 1996), as its ability to account for a large range of findings proved intriguing. However, by the mid-1990s, Baddeley called for closer exploration of the central executive (Baddeley, 1996), a neglected, yet probably the most important of the working memory components. Further research and evaluation of the model led the author to add another slave system, the episodic buffer (Baddeley, 2000). This latest addition was motivated by the need to solve some persistent problems, such as the interface with long-term memory or the need to account for such phenomena as prose recall

[2] Since our concern lies mainly with interpretation, detailed discussion will be limited to the phonological loop. It is assumed that the visuospatial sketchpad plays no or only a marginal role in interpreting, a predominantly verbal task.

(recall of coherent strings of text such as complete sentences, as opposed to lists of individual words), where people typically score much higher than would be possible according to the limitations assumed for the phonological loop. The episodic buffer thus serves as a mental workspace which stores processed and integrated information. The model, as depicted in Figure 2, also allows for the distinction between fluid systems, which serve general processing (e.g. temporary storage), and crystallized systems, which allow for long-term storage and accumulation of knowledge (Baddeley, 2000). The fluid systems are supposed to be fairly stable, unaffected by learning, while the crystallized systems are the exact opposite – very much the result of learning. This distinction is important in the context of interpreting as an acquired skill. A large proportion of research into working memory in interpreting to date has focused on testing those components of working memory which are classified as fluid systems. Based on the theoretical model, and the predictions derived from it, it is so far not clear why interpreters should exhibit larger working memory capacity of the fluid components. This issue will be discussed further in chapter 4.

2.2.2. Ericsson and Kintsch: Long-Term Working Memory

A different approach to working memory was adopted by Ericsson and Kintsch. While most working memory research aims at discovering the nature of pure working memory, Ericsson and Kintsch are interested in how working memory functions in more realistic scenarios. Specifically, they address the question of how working memory supports skilled performance, ranging from instances of highly specialised activities, such as expert chess playing, to more everyday and yet very skilled activities such as reading and comprehension. Their analysis of such expert performance led to the proposal of long-term working memory (LT-WM; Ericsson and Kintsch, 1995). According to Ericsson and Kintsch, the traditional working memory (or short-term memory) concept is incompatible with real-life skilled performance on at least four counts: experts are capable of maintaining much more information than predicted by the capacity limits constraining WM; expert performance can be interrupted by another, attention-demanding task and later resumed with very little disruption to memory; experts are very accurate in their recall even if the recall task has not been expected; and the storage capacity of STM is fixed, while experts are capable of expanding it. All these issues are addressed in the LT-WM model. Crucially, Ericsson and Kintsch do not attempt to replace existing STM and WM models, but rather make an addition. Their LT-WM model arguably applies only to behaviour and tasks which are well practiced and to material which is familiar. LT-WM is proposed to be a “set of acquired mechanisms that enables experts to expand the functional capacity of their working memory system for specific types of materials in activities within their domain of expertise without altering the general capacity limits of [short-term working memory]” (Ericsson and Delaney, 1998:95). Importantly, LT-WM relies on storage in LTM. This is the main explanatory element behind the above mentioned issues: the amount of information can exceed the traditional STM capacity because it is stored in LTM and as such is more durable, hence less vulnerable to disruption. LT-WM is thus acquired, specific to a particular area of expertise, and the mechanisms supporting it are not directly transferable to another domain (for example, expert memory for digits does not imply expert memory for consonant strings - Ericsson and Delaney, 1998).

The above claim about LT-WM being an addition rather than a substitution needs qualification. The area of overlap between LT-WM and more traditional WM models becomes apparent when attempting to define an “area of expertise”. Ericsson and Kintsch (1995) include under expert performance such activities as reading and comprehension. These areas are in the focus of the traditional WM research as well, hence assuming that text which is being processed during reading and comprehension is being transiently stored in a separate WM store, while LT-WM assumes that reading is a skilled activity supported by LTM (Ericsson and Kintsch, 1995; Kintsch, 1998). Furthermore, the LT-WM concept does not do away with STM completely. While most information necessary for a successful execution of the task is available in LTM, it is accessed through specific retrieval cues available in STM. This seems to be the weaker point of the LT-WM model. The authors do not explain the mechanisms supporting the maintenance of the retrieval cues. Assuming that they are stored in the traditional STM (Ericsson and Delaney, 1998), they should be subject to the same limitations and constraints as other non-familiar material, such as a string of unrelated digits, i.e. there should be a capacity limit on the number of cues that can be maintained active, their maintenance should be vulnerable to interference, and the number of cues that can be recalled should be fairly fixed (once the number of cues reaches the capacity of the STM store, as the capacity is assumed to be stable throughout one’s adult life).

2.2.3. Cowan: Activated Long-Term Memory

A third approach was adopted by Nelson Cowan (1988, 1995), who conceptualises working memory as an activated part of long-term memory (Figure 2). According to this view (Cowan, 1999), long-term memory contains an activated subset of items. These items are the content of working memory, but are outside awareness. Only a small proportion of these items are directly accessible to awareness: these items are, in Cowan’s words, in the focus of attention. The concept of working memory is thus hierarchical – the focus of attention contains a small number of items directly available for processing. These are a subset of the activated memory. The activated memory contains highly activated items which are, nonetheless, available for processing only indirectly through inclusion in the focus of attention. This activated memory is in turn a subset of long-term memory. Items in long-term memory are not active, but can become a part of working memory if they receive enough activation (and eventually they can move to the focus of attention). The crucial component, the focus of attention, is controlled by a central executive component responsible for directing attention and controlling voluntary processing. Moreover, attention can be captured more directly and automatically by stimuli (e.g. loud noise or stimuli perceived as relevant, such as one’s own name, etc.).

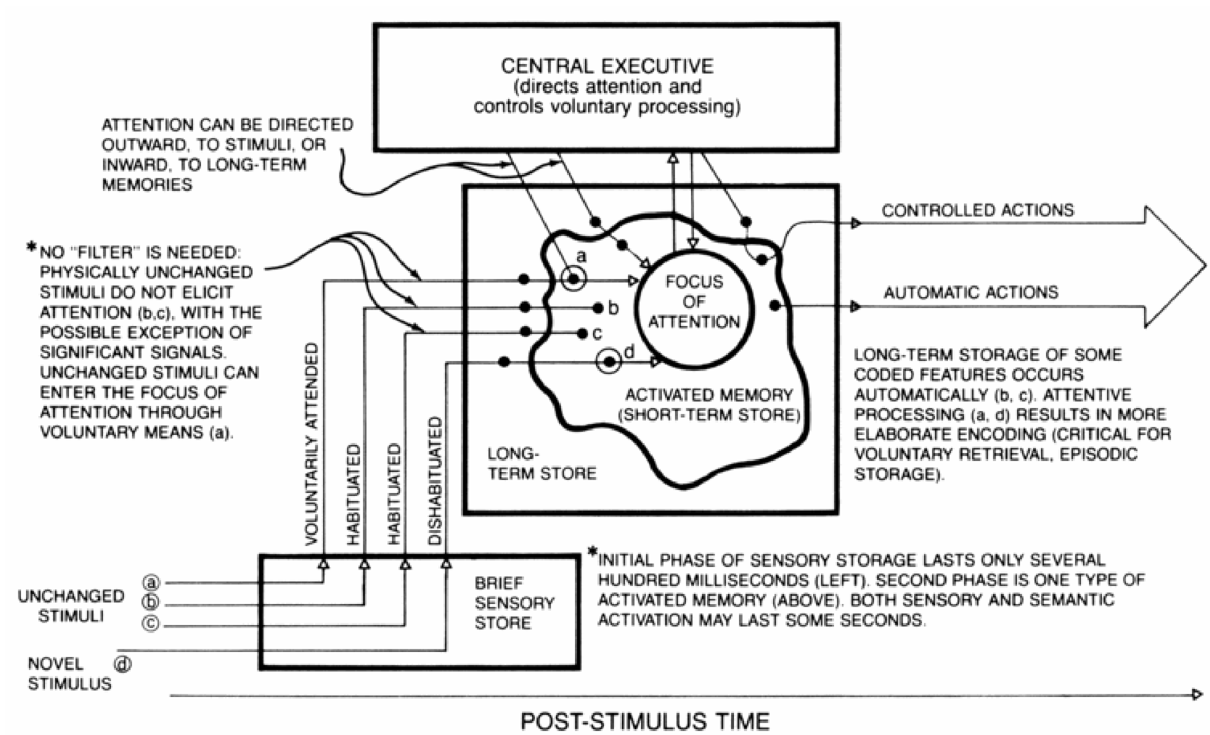

Figure 2. The working memory as an activated part of long-term memory (From Cowan, 1988)

Cowan proposes two types of limitations on working memory: time limitations and capacity limitations (Cowan, 1999). The focus of attention is subject to capacity limitations. Its estimated capacity is around ± 4 items. On the other hand, the activated memory is subject to time limitations. Unless activation of the items within the activated memory is maintained, it will decay and eventually drift out of the activated memory. The decay time is estimated to be around 10-30 seconds. Activation can be maintained through a rehearsal-like process of moving the item into the focus of attention. Interestingly, Cowan suggested that there is no capacity limit on the number of items concurrently activated, i.e. held in the activated memory.

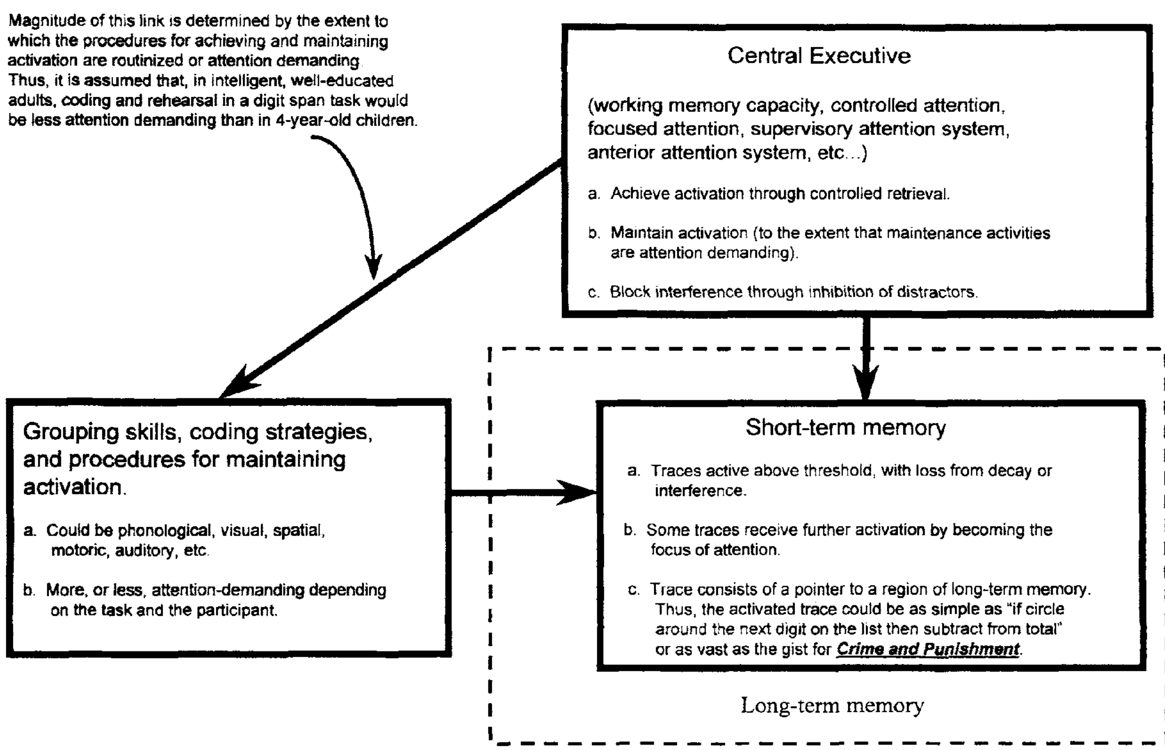

Figure 3. The working memory structure model by Engle, Tuholski, Laughlin and Conway (1999) (From Engle et al., 1999)

The basic tenets of Cowan's model have been recently empirically supported and extended by Oberauer (Oberauer, 2002; Oberauer and Göthe, 2006; Oberauer, 2006). Oberauer's model builds on Cowan's model and develops further the mechanisms of the focus of attention. Moreover, work by Conway and Engle (e.g. Conway and Engle, 1994; Engle et al., 1999; Engle and Kane, 2004) further provides both theoretical argument and empirical support for Cowan's model.[3] Their claim is that the crucial component of individual differences in working memory is controlled attention, responsible for maintaining goals, protection of task execution against interference, effortful processes, etc. They extend Cowan's basic model by explicitly including the executive component and by allowing for domain-specific strategies (see Figure 3).

2.3. Working Memory Models: Discussion

In the previous section, we offered a short overview of three models of working memory. It should be clear by now that working memory as a concept is a very complex phenomenon. Each model places a different emphasis on different aspects of working memory, and reconciliation of the models is by no means easy. In this section, we will point out some of the major differences between the models.

The first difference concerns the view of working memory as a structural or a functional entity. Baddeley's model is a good example of a structural model (cf. Engle and Kane, 2004). The basic assumption is that working memory constitutes a separate entity with more or less independent components, and the research aim is to identify the components and define their properties. On the other hand, Ericsson and Kintsch and Cowan postulate their models more in functional terms. This distinction is important for several reasons. The structural approach assumes that working memory is a separate entity with a fixed structure. The structure supports (and limits) cognitive performance. The functional approach, on the other hand, defines working memory in terms of processes or purpose, rather than structures. Working memory is thus defined as "temporary storage and processing of information" (functional view), and it can be supported by any neuroanatomical structure, including support by different structures on different occasions. Working memory is seen as a set of mechanisms which enable short-term maintenance of task-relevant information to ensure successful task completion (cf. Cowan, 1999). The models by Cowan, and Ericsson and Kintsch are less concerned with identifying specific "stores", but rather focus on the processes. Both Ericsson (Ericsson and Delaney, 1999) and Cowan (1999) openly refuse to limit their models to a predetermined structure, allowing working memory to make use of whichever mechanisms are available or appropriate. The reason for this difference may be

[3] However, Cowan sees some important differences between his work and the work by Engle and colleagues (Cowan, 1999).

partly historical. Baddeley's model evolved from earlier models assuming a necessary separate store for information which needs to be maintained for short periods of time. Ericsson and Kintsch's and Cowan's models are younger and address the more recent issue of interface between working memory (current task processing) and long-term memory (knowledge structures). The conceptual dissociation of working memory and long-term memory certainly holds, but there are doubts as to their neuroanatomical dissociation (e.g. Ranganath and Blumenfeld, 2005; Ruchkin, Grafman, Cameron and Berndt, 2003). Baddeley and Logie (1999) defend the separate-stores view, and point out the important function of WM as a gateway of novel stimuli, which were not previously encountered and hence have no representation in long-term memory.

Secondly, and more importantly for our topic, the models differ in their treatment of an executive component. Ericsson and Kintsch do not explicitly assume a separate executive component. Skilled performance seems to be guided mostly by processes relying on previous experience. Performers anticipate upcoming stimuli, use goal-directed strategies, rely on various cues, etc. On the other hand, Baddeley and Cowan assign a crucial role to their executive components. In both models, this component is very closely related to attention, and it is associated with effortful, conscious processing. In Cowan's model, the central executive controls and directs attention and voluntary processing. Similarly, Baddeley assumes that the central executive is responsible for the coordination of two (or more) tasks, selective attention, strategies switching, and manipulation of information in long-term memory (Baddeley, 1996; Baddeley, 2002). The crucial role of the executive control is supported by current trends in research, which seem to converge on the idea that the executive control is largely synonymous with controlled attention. Controlled attention thus emerges as a separable entity. Moreover, individual differences research suggests that controlled attention is more important (is a better correlate) for higher-cognition activities than the storage component of working memory (e.g. Engle, Tuholski, Laughlin and Conway, 1999; Conway and Engle, 1994; Feldman Barrett, Tugade and Engle, 2004; Lépine, Bernardin and Barrouillet, 2005; Cowan, Elliott, Saults, Morey, Mattox, Hismajatullina and Conway, 2005; Engle, 2002; Hester and Garavan, 2005; but see Colom, Rebollo, Abad and Shih, 2006; Buehner, Krumm and Pick, 2005 for a view supporting the storage component as the most important element of working memory).

Thirdly, the models differ on the assumed capacity of working memory, both in terms of the size of the working memory, and in terms of the nature of its limitations. Baddeley assumes a temporal limitation, whereby the phonological loop can maintain approximately 2 seconds worth of verbal material. The actual amount of material stored can differ among individuals depending on their speed of articulation: those who can pronounce more in two seconds are also able to remember more (but see Baddeley and Logie, 1999, for a less definitive view on the working memory capacity). Cowan (1999), as mentioned above, assumes a double limitation, both temporal and in terms of capacity. On the one hand, items in the activated memory are subject to temporal decay within 10-30 seconds, if their activation is not maintained. On the other hand, items in the focus of attention are limited to ± 4 items, but can be held in attention for a substantial amount of time (Cowan, 1999). Ericsson and Delaney (1999) assume that in principle there is no limit on the number of activated items. However, as mentioned above, Ericsson and Kintsch’s model assumes retrieval cues to be maintained in short-term memory, and it is not clear how many cues can be held active at the same time and for how long.

To conclude, in this short overview we presented three models of working memory which we believe are representative of the current debate in the field, and which are at the same time relevant for interpreting research. We highlighted the issues of structural vs functional modelling, executive control and attention, and the nature and quantification of working memory capacity.

3. Working Memory and Interpreting

In the long tradition of research into cognitive processes involved in (simultaneous) interpreting, working memory is among the components that received most attention in both theoretical writing and empirical studies. Basically all major cognitive (process) models of SI assume that working memory plays a crucial role, and several models are built directly on the concept (Gerver, 1976; Moser, 1978; Darò and Fabbro, 1994). It must be mentioned here that the majority of theoretical considerations of working memory and its role in SI are limited to storage functions. Executive functions have rarely been taken into considerations, and to date no empirical testing of the central executive has been carried out. The aim of this section is to sketch out some of the lines of thought on the role of working memory in simultaneous interpreting and contrast them with empirical work in interpreting research. Similarly to the section on general models of working memory, this section is very selective in terms of models and the empirical studies to be discussed. The objective is to provide an analysis of the various approaches to working memory, both in terms of theoretical thinking and empirical testing, rather than an exhaustive overview of all previous work on the topic.

3.1. Process Models of Simultaneous Interpreting and Working Memory

One of the first cognitive models of simultaneous interpreting was introduced by David Gerver in the early 1970s (Gerver, 1975, 1976). Gerver conducted a number of experiments with professional interpreters and based on the results proposed a sequential model of mental processing during interpreting (Figure 4). The model focuses on a system of short-term stores for the different stages of text processing. Gerver assumed that the source text is stored in an input buffer, from where it proceeds for further processing. The input buffer also stores a segment of the input text while the processor is busy with a previous segment.

The actual text processing is, according to Gerver, performed in co-operation with long-term memory, which activates the appropriate linguistic units. Gerver assumed that this stage of processing is purely linguistic, and did not consider it any further (Gerver, 1976). The processed material is then ready for output – via an output buffer, where it undergoes optional monitoring.

Gerver's model is interesting in a number of ways. To begin with, it is the first model which considers both short-term and long-term memory in SI, providing at least a somewhat explicit description of the process. Secondly, it is interesting that Gerver proposed two buffers, one for each language (source and target languages). This concept is very modern, as it incorporates a fairly recent finding (end of the 1960s) that processing is not confined to a single channel and that information[4] from several sources can be processed in parallel. On the other hand, this view of storage is not in line with current models of working memory which do assume separate stores but where each store serves a different modality. Separate buffers for the input and output languages are thus a unique aspect of Gerver's model, so far without theoretical or empirical support. Thirdly, Gerver uses the term *operational memory* or *working memory*, but

[4] *Information* is to be understood in the psychological sense of *information processing*, where any input, both internal and external, is considered to be information.

does not specify in his model which segments of the process are performed by working memory, nor whether he considers working memory to be a structural or a functional entity (cf. Gerver, 1975). This issue has, unfortunately, remained unaddressed, since Gerver's model (and all other process models) was not tested nor developed further on a theoretical level.

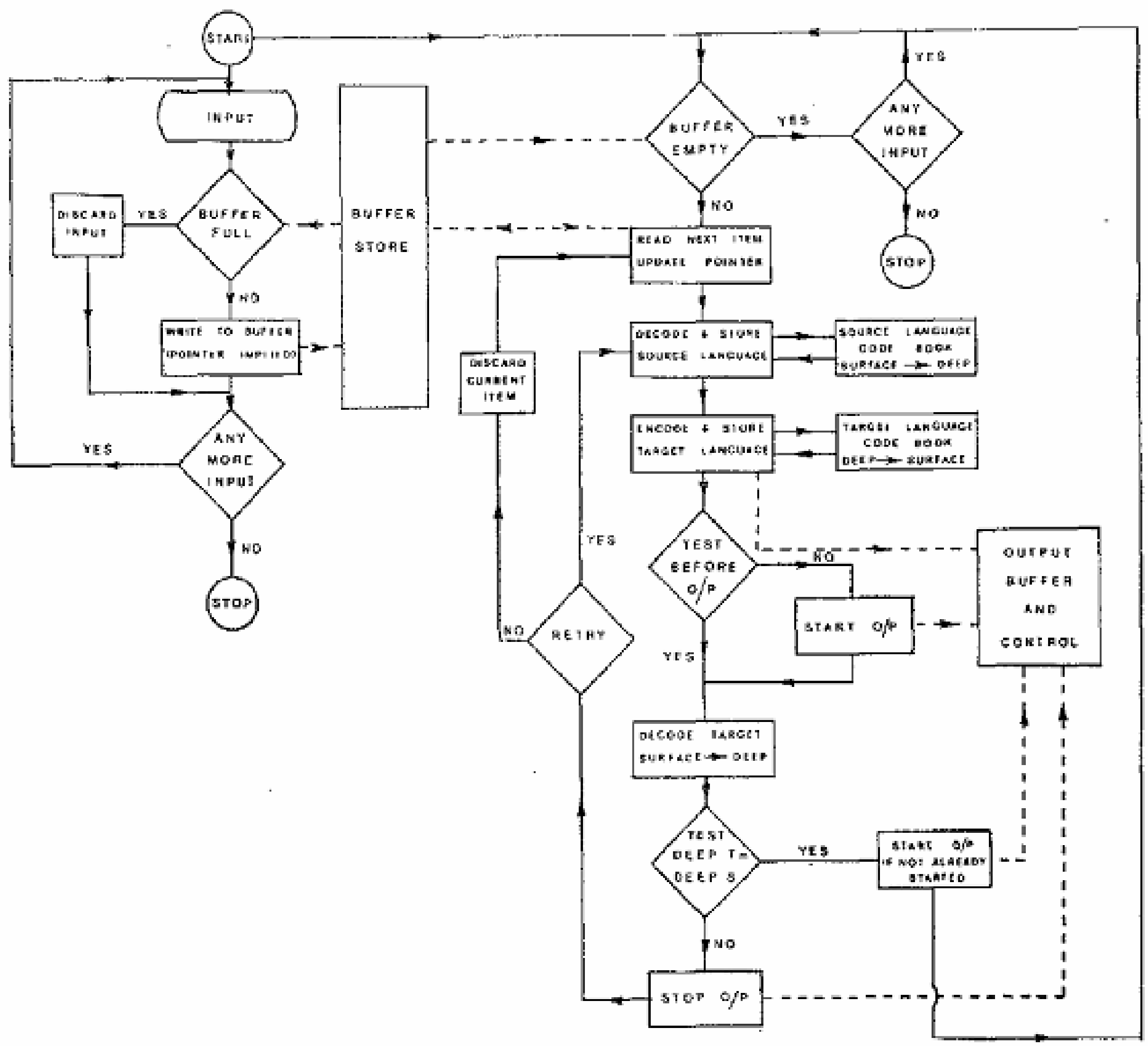

Figure 4. Model of SI by David Gerver (1975)

Another process model of simultaneous interpreting was proposed by Barbara Moser in the mid-1970s (Moser, 1978; Figure 5). Her model too assigns a crucial role to working memory. Unlike Gerver, Moser is more explicit as to specific process segments. Barbara Moser uses a different term – *generated abstract memory* (GAM), but mentions specifically that it is identical to short-term memory (Moser, 1978). Her model is also interesting on a number of levels. First of all, Moser seems to consider working memory (at least as far as is apparent from the depicted model and from the accompanying verbal description) to be both a structural and functional component. GAM performs several important tasks. It stores processed chunks of text (strings of (syntactically and semantically) processed words, although it is not clear to which extent they are processed). This is the memory (storage) function proper. GAM also performs a recoding task in co-operation with a conceptual base, i.e. it is involved in the linguistic transformation. Throughout these operations, GAM is strongly linked to long-term memory, which stores all concepts, mental lexicons, syntax and grammar rules, etc. In Moser's view, GAM is explicitly involved in production as well. This makes the placement of the paraphrasing and prediction functions outside GAM somewhat incoherent. In the model, GAM does not encompass processes of auditory perception (at the beginning) and articulation (at the end). Thus the reasons for the exclusion of paraphrasing and predictions are not entirely clear, nor is it clear which other structural component performs these tasks. A second interesting aspect of this model is that GAM is equated with short-term memory, and that its storage function is emphasised. Short-term memory in cognitive psychology in the early 1970s was considered to be a purely passive store. Moser's model is ambiguous in this respect. By including the recoding functions in GAM, Moser proposes a very modern concept of working memory, which seems to include executive functions. Unambiguous interpretation of her model is, unfortunately, impossible on the basis of her short article (Moser, 1978).

The third and more recent model we will briefly discuss was proposed by Valeria Darò and Franco Fabbro (Darò and Fabbro, 1994). The authors merged contemporary findings and thoughts from psychology of memory, and used them to inform their model of SI (see Figure 6), which – like Gerver's model – centers on memory and disregards other processes and structural entities. Among the most interesting features of the model is the fact that it is very much in line with current thinking about memory systems. The model assumes two memory systems: working memory and long-term memory, both of which are further fractionated into sub-systems. The working memory system is based on the model by Baddeley and Hitch (1974, Baddeley, 1990), but Darò and Fabbro adopt only the verbal slave system and the central executive component.

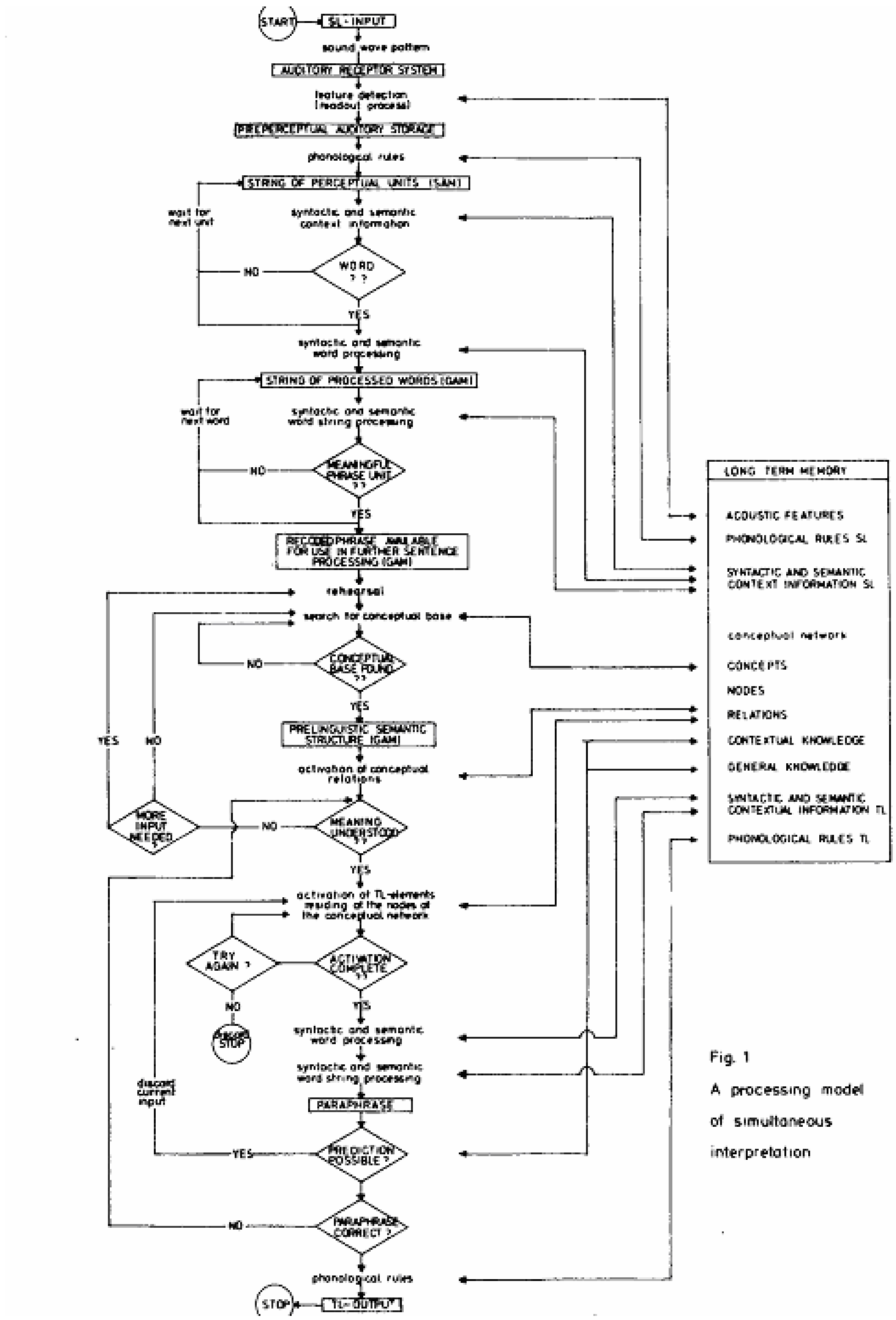

Figure 5. Model of SI by Barbara Moser (1978)

Secondly, as is apparent from the model, working memory serves as a gateway for source language input. Working memory serves primarily as a passive store of the source text, but the target language interferes with this function. The target language thus limits the capacity of working memory. Thirdly, it is interesting that the authors adopted the central executive, but did not assign it any specific task or function. That may have several reasons. One, this neglect is fully in line with the state of the art in psychology at the time, when researchers were also primarily interested in the storage functions. The central executive component was proposed in the original model in 1974 (Baddeley and Hitch, 1974), but attracted more attention only in mid 1990s, after Alan Baddeley called for more research into the executive functions of working memory (Baddeley, 1996). Another reason may be that the authors were explicitly interested in aspects of verbal memory. A third interesting aspect of the model is that the actual translation processes are performed by two separate modules. Each module serves for translation in one direction – from the non-native language into the native language, and from the native language to the non-native language. It would be interesting to know whether two more modules would be needed for each non-native language an interpreter works from/to.

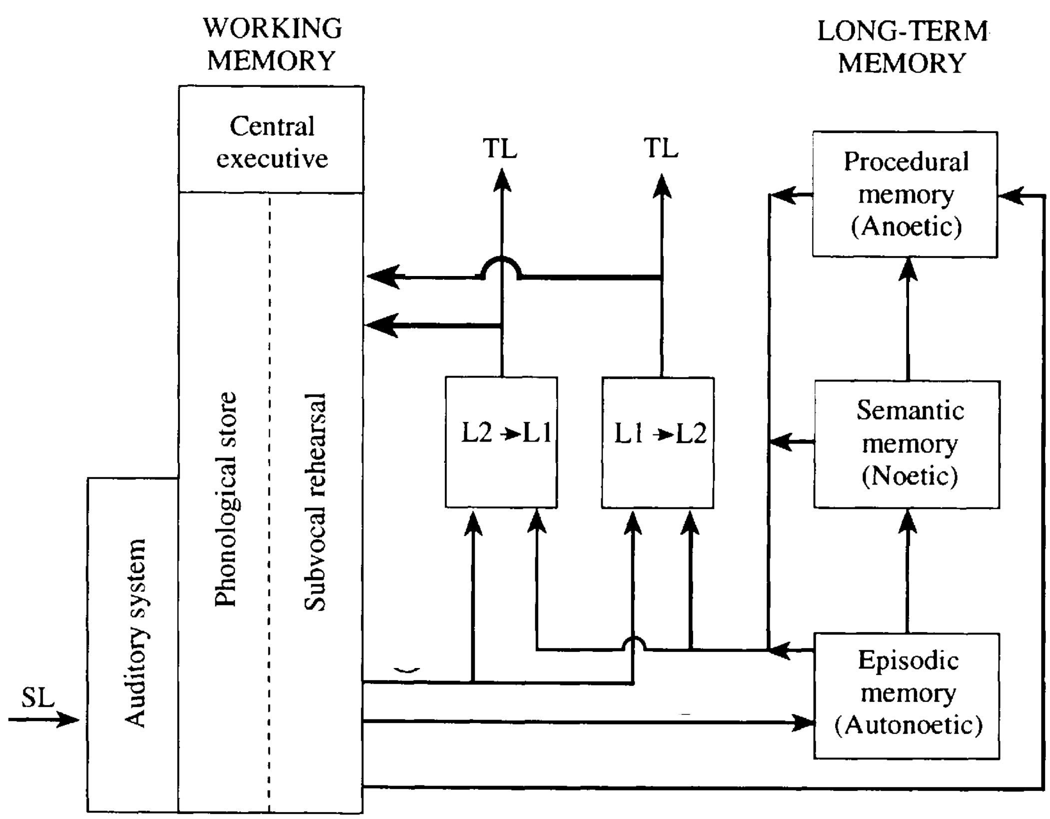

Figure 6. Model of SI by Darò and Fabbro (1994)

3.2. Working Memory and Its Role in Interpreting Process Models

A common feature of the three models briefly described in the previous section is that they put working memory into the centre of the interpreting process. This is, after all, true of the majority of SI process models (cf. Gile, 1995, 1997; Mizuno, 2005, see also Seleskovitch, 1968/1978). However, the models do differ significantly in their conceptualisation of the specific tasks working memory performs during the interpreting process.

The first difference is due to the period of origin of the model. All models are more or less based on the contemporary state of the art in cognitive psychology. Thus Gerver's model, which comes first chronologically, conceptualises working memory as a passive store of verbal input. Also Darò and Fabbro consider only the storage function, although their model already includes a central executive component. On the other hand, Moser (Moser, 1978), whose model is only a few years younger than Gerver's, assigns a fairly broad range of co-ordination and executive functions to working memory. It is not fully clear from the model, whether these tasks are performed by working memory (GAM in Moser's terminology) itself, or whether working memory serves as a kind of workspace, where the verbal material to be processed is gathered, while the actual processing is done by independent structural entities. If the latter, Moser's proposal would be similar to Darò and Fabbro's model, which assumes independent and self-contained modules responsible for the actual translation. Moser's model is thus ambiguous, but the fact that she placed these functions within working memory, is in itself a very modern concept, fully valid 30 years after the model had been proposed.

Another important difference between the models is the amount of available empirical support. As far as we know, Gerver's and Moser's models were never independently empirically tested. They represent theoretical models, based on contemporary thinking in cognitive psychology modified to reflect personal experience or partial empirical studies, but they were not submitted to a subsequent test. On the other hand, Darò and Fabbro's model is based on general theories of memory. Their specifications for purposes of SI are based on a fairly specific empirical study. Admittedly, only one study was carried out, yet among the SI models even this modest test is unique.

A third difference between the models is the proportion of the process (or amount of processing) ascribed to working memory. All models consider working memory to play an important role, but assign a differing amount of “work” to it. Gerver’s and Darò and Fabbro’s models assume that the interpreting process relies on working memory, long-term memory and unspecified translation mechanisms. On the other hand, Moser’s model makes do with working memory and long-term memory only. Moser’s model is then the only model where working memory seems to be the main interpreting mechanism.

These differences directly affect their use in interpreting research. The most flexible, in our opinion, is Moser’s model, which allows for direct testing.[5] This is not applicable to the other two models where working memory plays a central, though only a supportive role. By proposing independent translation modules, the models raise the question whether working memory is employed in interpreting above and beyond its use in normal life. This is an important point for empirical testing of the role of working memory in interpreting, which will be discussed in the next section. As will be shown, most research is motivated by this very rationale: interpreters use working memory to maintain verbal material which awaits processing.

3.3. Empirical Studies of Working Memory in Interpreters

Working memory seems to be an attractive research topic picked up by a number of researchers. This section, like previous sections, presents only a selection of the available empirical studies, to illustrate the various approaches to studying working memory in the context of interpreting.

The first study we will focus on was conducted by Presentación Padilla and colleagues (Padilla, Bajo, Cañas and Padilla, 1995). The authors based their study on contemporary literature, which made claims as to the necessity of good short-term/working memory in interpreters (Darò, 1989; Seleskovitch, 1968/1978). Their rationale was that excellent memory is a prerequisite for the acquisition of simultaneous interpreting skills, and that memory is further improved through interpreting training. These hypotheses led to specific predictions that a comparison of three groups (interpreters, interpreting students and bilinguals without interpreting experience or training) would demonstrate that interpreters have the largest memory capacity, and students have a larger capacity than non-interpreters. To test these predictions, Padilla et al. used a classical digit span test. In this test, participants are presented with series of digits. Each series

[5] Such testing would not be methodologically trivial, but the model specifies relationships between working memory and interpreting.

consists of two to nine digits and the presentation can be either visual or auditory. Participants' task is to recall the digits in the order in which they were presented. Padilla et al. used the auditory version. They interpreted the results as showing that interpreters do indeed demonstrate a larger working memory capacity than non-interpreters.[6] Another test used combines memory storage and processing. The specific test used was the reading span test (Daneman and Carpenter, 1980), in which participants are visually presented with sentences. Their task is to read the sentence aloud (processing) and remember the last word (memory). Similarly to the digit span test, the number of sentences in a set varies; a typical test will present sets with two to six sentences. Working memory capacity is then calculated as the number of correctly recalled words in the correct order. This test is one of the most frequently used tests of working memory. A common modification is its auditory version – the listening span test. Also on this test, interpreters demonstrated higher capacity than other groups (with the same qualification as to the statistical reporting).

Another approach can be illustrated in a study by Chincotta and Underwood (1998), who focused on one specific aspect of working memory: articulatory interference. A number of empirical studies have shown that memory trace is affected when it cannot be rehearsed. This is one of the fundamental aspects of the working memory model by Baddeley and Hitch (1974). It has been also shown that such rehearsal can be effectively prevented by concurrent articulation. Since concurrent articulation is common in simultaneous interpreting, the issue of interference is very interesting for our domain. The most common assumption is that experienced interpreters will be affected by concurrent articulation less than interpreter trainees and non-interpreters. Chincotta and Underwood conducted an experimental study in which they asked participants to perform the digit span test in two experimental conditions. In one, the digit span was administered in its traditional form, in the other, participants were asked to repeat aloud an unrelated word throughout the digit span test, thus interfering with the memory trace for digits. The assumption that interpreters will be less affected by the concurrent articulation was not supported.

[6] Unfortunately, the results in this study and in another study by Padilla et al. (Bajo, Padilla and Padilla, 2000) are not correctly reported. The authors do not present descriptive statistics, group means are thus available only in charts. Inferential statistics are incomplete (only main effects are reported, but not pairwise tests). The tests show that there are significant differences between the groups, but the absence of further tests makes it impossible to say between which groups exactly.

A third type of approach consists of testing interpreters with a different level of interpreting expertise. This approach can be illustrated by Minhua Liu's doctoral dissertation (2001, published in an abridged form as Liu, Schaller and Carrol, 2004). Liu asked three groups of interpreters (experienced interpreters, advanced students and novice students) to interpret several types of text. Liu has pre-selected segments of the texts and used them to evaluate the interpreters' ability to select and transfer primary and secondary information and other aspects of interpreting. All participants also completed the listening span test. Liu found out that the groups did not differ in their working memory capacity, but did show significant differences in their interpreting performance. Liu interpreted her results as showing that working memory is not crucial for simultaneous interpreting and that interpreters rely on other cognitive mechanisms.

4. Working Memory and Interpreting: Where Next?

These three types of studies are fairly representative of working memory research in interpreting. Although there are differences among these approaches, they also share a number of features. Most empirical studies are based on the hypothesis that interpreters have a larger working memory capacity than non-interpreters, and the studies are designed to test this assumption. The least frequent is the third type: empirical studies of working memory rarely include interpreting tests. Instead, it is assumed that the interpreting skill causes permanent changes in cognitive structures, and that these changes will be apparent when interpreters are compared to non-interpreters using standard tests of working memory. This assumption is also behind models such as Gerver's or Darò and Fabbro's: working memory in interpreters is not structurally or functionally different from the normal population, and interpreters use it mostly to maintain verbal material. Such intensive practice then results in a larger working memory capacity than can be found in the normal population. However, this hypothesis has never been reliably corroborated. Studies of the first type (comparison of working memory capacity in interpreters and non-interpreters) are most common: about half of them has demonstrated a larger capacity in interpreters, the other half has failed to do so. The preference for this type of research is probably largely due to the fact that most working memory research in simultaneous interpreting takes the Baddeley and Hitch model (and its assumptions) as its starting point. This is a very interesting fact in itself, as the tests are designed to measure the storage capacity of working memory, i.e. the mechanism which is part of the fluid systems assumed to be stable across one's adult life. Yet at the same time, the hypothesis driving this type of research is that interpreters will demonstrate a larger working memory capacity developed as a result of practice. It is not clear how this claim can be theoretically justified in the context of the Baddeley and Hitch model. As we have discussed in Section 1, there are a number of other competing approaches, but these are only slowly gaining recognition in interpreting studies (see Mizuno's 2005 proposal for Cowan's model as the basis for working memory in interpreting). Baddeley and Hitch's model has a highly structural focus and may not be best suited to answer research questions interesting for interpreters.

Related to the above is the very interesting sharp discrepancy between the theoretical models of working memory in interpreting and the empirical studies. Most studies are looking to confirm better working memory capacity in interpreters than in non-interpreters, yet the theoretical models do not make it clear why such higher capacity would be needed. Two out of the three models discussed see the role of working memory as buffer stores for verbal material waiting to be processed in specialised modules. Since the time lag in simultaneous interpreting is usually just a few seconds, well within the normal storage limit, it is not entirely clear why interpreters should exhibit increased storage capacity. The third model seems to emphasise working memory as a coordinating body, yet these functions are not really tested.

Taking all this into consideration, we would like to propose a new approach to exploring the involvement of working memory in interpreting. First of all, other working memory functions above and beyond its maintenance capacity should be included in the testing. This means including tests of its executive functions. For example, Moser-Mercer (2005) proposed that controlled attention is the decisive element in the ability to interpret, and other executive functions are available for closer examination as well. As stated in Section 2, the state of the art in basic working memory research assumes that working memory executive functions include protection of task against interference, effortful processing, etc. These functions are highly relevant in the process of interpreting, and it would be worthwhile to explore them in more detail.

Secondly, we believe that interpreting must be included more prominently in the tests. So far, most empirical studies include interpreting only implicitly by comparing interpreters to non-interpreters. Such an approach is valid, but relies heavily on the assumption that the ability to interpret causes permanent changes in the interpreters' cognitive structures and that these changes can be detected with standard tests. In contrast, studies such as Liu's allow a more direct interpretation of results, because they include a direct test of interpreting performance. Given working memory involvement in higher cognitive activities (cf. Section 2), it is fairly certain that working memory is involved in simultaneous interpreting as well. It is less clear whether such involvement necessarily requires that interpreters exhibit better working memory than non-interpreters. To detect the involvement of working memory in interpreting, a more direct comparison is needed. We believe that Liu offers a good method of doing so: taking a measure of working memory and a measure of interpreting, and comparing them across individual interpreters. That way we can look for relationships between the various working memory functions and various aspects of interpreting. Such an approach is necessary to help make a stronger theoretical case for the role of working memory in interpreting above and beyond the simple statement of its necessity.

References

Atkinson, Richard M. and Shiffrin, Richard M. 1971. "The control of short-term memory". *Scientific American* 225: 82-90.

Baddeley, Alan D. 1990. *Human Memory. Theory and Practice*. London: Lawrence Erlbaum Associates.

Baddeley, Alan. 1996. "Exploring the central executive". *The Quarterly Journal of Experimental Psychology* 49A (1): 5-28.

Baddeley, Alan. 2000. "The episodic buffer: A new component of working memory?". *Trends in Cognitive Sciences* 4 (11): 417-423.

Baddeley, Alan D. 2002. "Is working memory still working?" *European Psychologist* 7 (2): 85-97.

Baddeley, Alan, Gathercole, Susan and Papagno, Costanza. 1998. "The phonological loop as a language learning device". *Psychological Review* 105 (1): 158-173.

Baddeley, Alan D. and Hitch, Graham J. 1974. "Working memory". In *The Psychology of Learning and Motivation: Advances in Research and Theory, Vol. 8*, G. Bower (ed). New York: Academic Press. 47-89.

Baddeley, Alan D. and Logie, Robert H. 1999. "Working memory: The multiple-component model". In *Models of Working Memory. Mechanisms of Active Maintenance and Executive Control*, A. Miyake and P. Shah (eds). Cambridge: Cambridge University Press. 28-61.

Baddeley, Alan D., Thomson, Neil and Buchanan, Mary. 1975. "Word length and the structure of short-term memory". *Journal of Verbal Learning and Verbal Behavior* 14: 575-589.

Bajo, María Teresa, Padilla, Francisca and Padilla, Presentación. 2000. "Comprehension processes in simultaneous interpreting". In *Translation in Context*, A. Chesterman, N. Gallardo San Salvador and Y. Gambier (eds). Amsterdam/Philadelphia: John Benjamins. 127-142.

Buehner, Markus, Krumm, Stefan and Pick, Marion. 2005. "Reasoning is working memory is not attention". *Intelligence* 33: 251-272.

Chincotta, Dino and Underwood, Geoffrey. 1998. "Simultaneous interpreters and the effect of concurrent articulation on immediate memory. A bilingual digit span study". *Interpreting* 3 (1): 1-20.

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

Colom, Roberto, Rebollo, Irene, Abad, Francisco J. and Shih, Pei Chun. 2006. "Complex span tasks, simple span tasks, and cognitive abilities: A reanalysis of key studies". *Memory and Cognition* 34 (1): 158-171.

Conway, Andrew R.A., Cowan, Nelson, Bunting, Michael F., Therriault, David J. and Minkoff, Scott R.B. 2002. "A latent variable analysis of working memory capacity, short-term memory capacity, processing speed, and general fluid intelligence". *Intelligence* 30: 163-183.

Conway, Andrew R.A. and Engle, Randall W. 1994. "Working memory and retrieval: A resource-dependent inhibition model". *Journal of Experimental Psychology: General* 123 (4): 354-373.

Cowan, Nelson. 1988. "Evolving conceptions of memory storage, selective attention, and their mutual constraints within the human information-processing system". *Psychological Bulletin* 104 (2): 163-191.

Cowan, Nelson. 1995. *Attention and Memory. An Integrated Framework.* New York/Oxford: Oxford University Press.

Cowan, Nelson. 1999. "An embedded-processes model of working memory". In *Models of Working Memory. Mechanisms of Active Maintenance and Executive Control*, A. Miyake and P. Shah (eds). Cambridge: Cambridge University Press. 62-101.

Cowan, Nelson., Elliott, Emily M., Saults, J. Scott, Morey, Candice C., Mattox, Sam, Hismajatullina, Anna and Conway, Andrew R.A. 2005. "On the capacity of attention: Its estimation and its role in working memory and cognitive aptitudes". *Cognitive Psychology* 51: 42-100.

Daneman, Meredyth and Carpenter, Patricia A. 1980. "Individual differences in working memory and reading". *Journal of Verbal Learning and Verbal Behavior* 19: 450-466.

Darò, Valeria. 1989. "The role of memory and attention in simultaneous interpretation: A neurolinguistic approach". *The Interpreters' Newsletter* 2: 50-56.

Darò, Valeria and Fabbro, Franco. 1994. "Verbal memory during simultaneous interpretation: Effects of phonological interference". *Applied Linguistics* 15 (4): 365-381.

Engle, Randall W. 2002. "Working memory capacity as executive attention". *Current Directions in Psychological Science* 11 (1): 19-23.

Engle, Randall W. and Kane, Michael J. 2004. "Executive attention, working memory capacity, and a two-factor theory of cognitive control". In *The Psychology of Learning and Motivation: Advances in research and theory, Vol.44*, B. Ross (ed). New York: Academic Press. 145-199.

Engle, Randall W., Tuholski, Stephen W., Laughlin, James E. and Conway, Andrew R.A 1999. "Working memory, short-term memory, and general fulid intelligence: A latent-variable approach". *Journal of Experimental Psychology: General* 128 (3): 309-331.

Ericsson, K. Anders and Delaney, Peter F. 1998. "Working memory and expert performance". In *Working Memory and Thinking*, R.H. Logie and K.J. Gilhooly (eds). Hove: Psychology Press. 93-114.

Ericsson, K. Anders and Delaney, Peter F. 1999. "Long-term working memory as an alternative to capacity models of working memory in everyday skilled performance". In *Models of Working Memory. Mechanisms of Active Maintenance and Executive Control*, A. Miyake and P. Shah (eds). Cambridge: Cambridge University Press. 257-297.

Ericsson, K. Anders and Kintsch, Walter. 1995. "Long-term working memory". *Psychological Review* 102 (2): 211-245.

Feldman Barrett, Lisa, Tugade, Michele M. and Engle, Randall W. 2004. "Individual differences in working memory capacity and dual-process theories of the mind". *Psychological Bulletin* 130 (4): 553-573.

Gerver, David. 1975. "A psychological approach to simultaneous interpreting". *Meta* 20 (2): 119-128.

Gerver, David. 1976. "Empirical studies of simultaneous interpretation: A review and a model". In *Translation. Application and Research*, R.W. Brislin (ed). New York: Garden Press. 165-207.

Gile, Daniel. 1995. *Basic Concepts and Models for Interperter and Translator Training*. Amsterdam/Philadelphia: John Benjamins.

Gile, Daniel. 1997. "Conference interpreting as a cognitive management problem". In *Cognitive Processes in Translation and Interpretation*, J.H. Danks, G.M. Shreve, S.B. Fountain and M.K. McBeath (eds). London/Thousand Oaks/New Delhi: Sage. 196-214.

Hester, Robert and Garavan, Hugh. 2005. "Working memory and executive function: The influence of content and load on the control of attention". *Memory and Cognition* 33 (2): 221-233:

Hitch, Graham J. 2005. "Working memory". In *Cognitive Psychology*, N. Braisby and A. Gellatly (eds). Oxford: Oxford University Press. 307-341.

James, William. 1890. *The Principles of Psychology*. New York: Henry Holt.

Jarrold, Chris and Towse, John N. 2006. "Individual differences in working memory". *Neuroscience* 139: 39-50.

Just, Marcel A. and Carpenter, Patricia A. 1992. "A capacity theory of comprehension: Individual differences in working memory". *Psychological Review* 99 (1): 122-149.

Kiewra, Kenneth A. and Benton, Stephen L. 1988. "The relationship between information-processing ability and notetaking". *Contemporary Educational Psychology* 13: 33-44.

Kintsch, Walter. 1998. *Comprehension. A Paradigm for Cognition*. Cambridge: Cambridge University Press.

Köpke, Barbara and Nespoulous, Jean-Luc. 2006. "Working memory performance in expert and novice interpreters". *Interpreting* 8 (1): 1-23.

Kyllonen, Patrick C. and Christal, Raymond E. 1990. "Reasoning ability is little more than working memory capacity?". *Intelligence* 14: 389-433.

Lépine, Raphaëlle, Bernardin, Sophie and Barrouillet, Pierre. 2005. "Attention switching and working memory spans". *European Journal of Cognitive Psychology* 17 (3): 329-345.

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

Liu, Minhua, Schallert, Diane L. and Carroll, Patrick J. 2004. "Working memory and expertise in simultaneous interpreting". *Interpreting* 6 (1): 19-42.

Miller, George A. 1956. "The magical number seven plus or minus two: Some limits on our capacity for processing information". *Psychological Review* 63: 81-97.

Mizuno, Akira. 2005. "Process model for simultaneous interpreting and working memory". *Meta* 50 (2): 739-752.

Moser, Barbara. 1978. "Simultaneous interpretation: A hypothetical model and its practical application". In *Language Communication and Interpretation*, D. Gerver and H.W. Sinaiko (eds). New York/London: Plenum Press. 353-368.

Moser-Mercer, Barbara. 2005. "Simultaneous interpreting and cognitive limitations. The acquisition of expertise as a process of circumventing constraints". Keynote delivered at the Workshop on "Cognitive aspects of simultaneous interpreting", 19-20 mai 2005 / May, 19-20, 2005, Université de Toulouse-Le Mirail.

Nordet, Lilian and Voegtlin, Lara 1998. *Les tests d'aptitude pour l'interprétation de conférence. La mémoire.* Mémoire pour l'obtention du Diplôme de Traducteur, École de Traduction et d'Interprétation, Université de Genève.

Oberauer, Klaus. 2002. "Access to information in working memory: Exploring the focus of attention". *Journal of Experimental Psychology: Learning, Memory, and Cognition* 28 (3): 411-421.

Oberauer, Klaus. 2006. "Is the focus of attention in working memory expanded through practice?" *Journal of Experimental Psychology: Learning, Memory and Cognition* 32 (2): 197-214.

Oberauer, Klaus and Göthe, Katrin. 2006. "Dual-task effects in working memory: Interference between two processing tasks, between two memory demands, and between storage and processing". *European Journal of Cognitive Psychology* 18 (4): 493-519.

Padilla, Presentación, Bajo, María Teresa, Cañas, José Juan and Padilla, Francisca. 1995. "Cognitive processes of memory in simultaneous interpretation". In *Topics in Interpreting Research*, J. Tommola (ed). Turku: University of Turku Press. 61-71.

Ranganath, Charan and Blumenfeld, Robert S. 2005. "Doubts about double dissociations between short- and long-term memory". *Trends in Cognitive Sciences* 9 (8): 374-380.

Redick, Thomas S. and Engle, Randall W. 2006. "Working memory capacity and attention network test performance". *Applied Cognitive Psychology* 20: 713-721.

Repovš, Grega and Baddeley, Alan. 2006. "The multi-component model of working memory: Explorations in experimental cognitive psychology". *Neuroscience* 139: 5-21.

Ruchkin, Daniel S., Grafman, Jordan, Cameron, Katherine and Berndt, Rita S. 2003. "Working memory retention systems: A state of activated long-term memory". *Behavioral and Brain Sciences* 26: 709-777.

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

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

About the author

Šárka TIMAROVÁ works as a research assistant at Lessius University College (Antwerp, Belgium). She trained as a conference interpreter at Charles University (Prague, Czech Republic), and followed her studies with a postgraduate research training programme (DEA in Interpreting) and Continuing Education Certificate for Interpreter Trainers (EP bursary) at ETI (University of Geneva, Switzerland). She is currently working on her doctoral dissertation in conference interpreting to be submitted to Charles University. She is specifically researching the

involvement of working memory in simultaneous interpreting and the applicability of these findings to interpreter training.

Address: Lessius University College, Department of Applied Language Studies, Sint-Andriesstraat 2, 2000 Antwerpen, Belgium
E-mail: sarka.timarova@lessius.eu