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WORKING MEMORY LOAD IN SIMULTANEOUS LANGUAGE INTERPRETATION: AN ERP STUDY

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Abstract. We utilized the event-related potential (ERP) technique to study neural activity associated with different levels of working memory (WM) load during simultaneous language interpretation (SLI). We pioneered the use of the technique on conference interpreters articulating overtly. The amplitude of the N1 component elicited by task-irrelevant tone probes was significantly modulated as a function of WM load but not the direction of interpretation. The N1 amplitude decreased with load, suggesting shallower processing under high WM load regardless of the direction.

Keywords: simultaneous language interpretation, ERP, working memory, attention

Introduction

Unlike monolingual communication, simultaneous language interpreting (SLI) involves a source message being perceived and processed almost concurrently with the production of an equivalent message in another language. A major challenge in SLI is managing a limited supply of working memory (WM) capacity and attention. Indeed, in SLI the interpreter usually begins her interpretation before the speaker has finished his sentence. Conversely, the speaker starts the next utterance before the interpreter has finished the translation of the previous chunk (Li, 2010; Teder et al., 1993). This highlights the critical role of working memory in the SLI pipeline, especially since it may not always be possible to maintain linearity in the target message (Corbetta, Shulman, 2002): some items have to be stored until a good syntactic opportunity presents itself for the much earlier item to be translated overtly. The interpreters maintain a lag of a few words or phrases to be able to put the words into context and perform transformations needed for a coherent target message to emerge. However, maintaining a large lag is costly: it requires that a certain amount of attentional resources be diverted from other cognitive tasks, one of which is processing the current part of the source message. In sum, SLI is a complex of temporally overlapping competing efforts, including listening and production (Corbetta, Shulman, 2002; Ilukhin, 2001), each of which is enabled by working memory and attention. In fact, there is evidence suggesting that both working memory and attention utilize a common pool of neural resources (Chernov, 1999). fMRI studies also show that attention and working memory are subserved by largely the same brain areas (Coch et al., 2005; Chernov, 2004). Under normal circumstances, when the source message is relatively easy to process and target equivalents are quickly and automatically retrieved from long-term memory (LTM), the interpreter maintains a comfortable décalage, rendering the source message with almost no omissions. But with a difficult, dense or obscure passage, the décalage usually becomes larger, reflecting the need for more time to process it. In such situations, maintaining the lag within reasonable limits requires a temporary boost in processing WM backlog, which takes extra attentional resources. These can be mobilized at the expense of other cognitive processes, one of which is listening. But mustering extra attention is particularly problematic as the interpreters' processing capacity is already stretched and stretching it further increases the risk of losing information either in WM or in the current chunk of the source message. Based on that view, large décalage can be used to identify periods in which the interpreter likely experienced a temporary problem in processing the source message. Specifically, we can investigate whether the hypothesized difficulty at times of increased WM load forces interpreters to conserve attentional resources, which otherwise would be spent on listening, to focus more on processing the information accumulated in WM. Put another way, does the interpreter's brain control the processing pressure by gating part of the auditory input at times of increased WM load? Prior studies on non-interpreters have shown that when a listener's attention is distracted, the amplitude of early P1/N1 event-related potentials evoked by task-irrelevant probes embedded in a speech stream is smaller than when the listener is fully focused on the task (Bartlomiejczyk, 2006; Gile, 1999; Cowan, 1998; Woods et al., 1984; Hink, Hillyard, 1976). Therefore, these early ERP components can be used as a suitable index of interpreters' level of attention to the source message at a given time.

In our study we predicted that at times of increased décalage and, consequently, heightened WM load, the interpreters' brains will partially suppress the processing of auditory stimuli. This seemed a likely scenario because when WM load is high, attention is more needed to ensure the proper processing of the information backlog stored in WM and the reduction of the processing load associated with it as soon as possible. We also examined whether the direction of interpretation had any effect on early ERP components and sought to identify a potential interaction between it and WM load. Informal introspective reports of professional simultaneous interpreters had suggested that interpreting from a source language into Russian is — all else being equal — harder than in the reverse direction. In this study we hypothesized that in L2-L1 SLI, listening effort is attentionally more demanding than in the reverse situation (L1-L2 SI).

To our knowledge, the hypothesis that large WM loads impair the processing of the auditory stimuli in SLI has never been tested experimentally in an ecologically valid setting. Here we present an EEG quasi-experiment designed to this end.

Method

Nine qualified interpreters (males aged 25–47, $M = 36.9$, $SD = 6.757$) participated in the study. All of them were L1 Russian speakers with an average of 10.65 ($SD = 6.675$) years of professional SLI experience. They were asked to interpret 8 United Nations speeches (4 Russian and 4 English). The speeches were originally delivered in a language other than Russian or English. Their translated versions were read by a bilingual speaker highly proficient in both Russian and English. The audio recording was digitally stretched to ensure a constant delivery rate of 105 wpm. Thus we eliminated the possible effects of individual speaker's voice features such as rate, pitch, timbre, loudness, prosody and accent. The total playback time was 53 minutes (excluding periods of rest between the speeches). To control for order effects, the speeches were played to the participants in a pseudo-random fashion according to a Latin square such that for every participant the text order was different. The audio of the source texts was mixed with probe stimuli (440 Hz 52 ms pure sine tones, including a rise and fall period of 4 ms) delivered with a jittered inter-stimulus interval (ISI) of 400–600 ms ($M = 500$ ms). These parameters were optimal in terms of maximizing the number of probes per second of experimental time while minimizing the effect of diminished ERP amplitude with shorter ISIs (Woods et al., 1984).

When all the participants' EEG data had been recorded, we made transcripts of both the original and translation. Then these transcripts were time-stamped and reformatted using a custom VBA script to allow us to calculate how many content words a particular participant lagged behind the speaker at any given time. These lags were used as an approximate estimate of WM load.

The continuous EEG was split into 500 ms epochs with a 100 ms baseline period, split into three groups corresponding to low, medium and high WM load estimated at the time of the probe onset, and averaged within these three groups and directions of interpretation (Eng-Rus and Rus-Eng). Due to a large between-subject variance in median WM loads, the boundaries between the three levels of WM load were computed individually for each participant and direction of interpretation (the 10^{th} quantile separated the low and medium load, and the 90^{th} quantile separated the medium and high load).

Results

A repeated measures ANOVA with *Direction* (Rus-Eng, Eng-Rus) and *WM Load* (Low, Medium, High) showed a significant main effect of *WM Load:* $F(2,16) = 7.828$, $p = .004$, $\eta^2_p = .49$. There was no main effect of language $F(1,8) = 0.168$, $p = .693$, $\eta^2_p = .02$, or interaction: $F(2,16) = 0.001$, $p = .999$, $\eta^2_p = .01$. A linear mixed effects model and a non-parametric randomization test with 1,000 resamples showed similar results.

Discussion and Conclusions

Our results show that larger lags (and higher WM load) are associated with shallower neural processing of task-irrelevant probes (and, by assumption, task-relevant information), as evidenced by smaller negativity in the N1 time

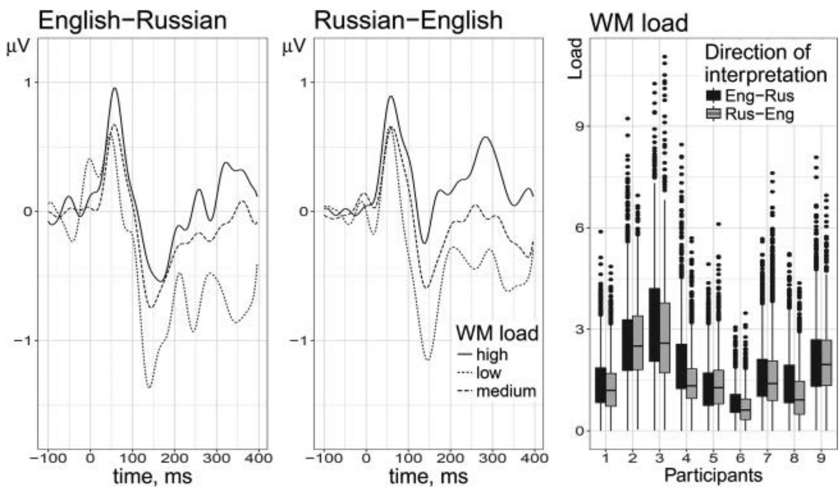

Figure 1. Results

range. This suggests an inverse relationship between working memory load and the depth of processing of the auditory information. The relationship is most likely mediated by attention, which in previous studies was shown to modulate N1 amplitude. These results are in agreement with the efforts model (Ilyukhin, 2001) and particularly the 'competition hypothesis' and reinforce the case for keeping WM load within reasonable limits during SLI. The question about how this can be achieved in practice is very relevant. Several studies (Sabri et al., 2014; Signorelli, 2013; Li, 2010; Gile, 1995; Hillyard et al., 1973) have shown that simultaneous language interpreters do use a range of strategies to manage their processing load (e.g., omitting redundancies in the source speech). None of the studies, however, have attempted to identify the neural states that determine — or at least bias — the choice of a particular strategy.

The value of this and future neuroimaging studies of SLI is that they could enable researchers to validate the current psycholinguistic models of SLI. Most importantly, they may be useful to SLI instructors in designing the most efficient current training curricula, practices and standards.

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Загрузка рабочей памяти в синхронном переводе: исследование методом вызванных потенциалов

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Аннотация. Мы применили метод вызванных потенциалов (ВП) для изучения электрической активности мозга при различных уровнях загрузки рабочей памяти (РП) в синхронном переводе. Впервые метод ВП использовался в эксперименте, предусматривающем перевод вслух. Амплитуда компонента N1 в ответ на тональные посылки существенно модулировалась уровнем загрузки РП, но не направлением перевода. При повышении нагрузки на РП N1 имели меньшую амплитуду, что указывает на более поверхностную обработку слуховой информации в периоды независимо от направления перевода.

Ключевые слова: синхронный перевод, вызванные потенциалы, рабочая память, внимание