

# **Cognitive Load in Relation to Non-Standard Language Input: Insights from Interpreting, Translation and Neuropsychology**

Michaela Albl-Mikasa<sup>1\*</sup>, Maureen Ehrensberger-Dow<sup>1</sup>, Andrea Hunziker Heeb<sup>1</sup>, Caroline Lehr<sup>1</sup>, Michael Boos<sup>2</sup>, Matthias Kobi<sup>2</sup>, Lutz Jäncke<sup>2</sup> and Stefan Elmer<sup>2\*</sup>

<sup>1</sup>Institute of Translation and Interpreting, Zurich University of Applied Sciences (ZHAW), Winterthur, Switzerland

<sup>2</sup>Auditory Research Group Zurich (ARGZ), Division Neuropsychology, Institute of Psychology, University of Zurich, Switzerland.

\*Corresponding authors

Short title: Cognitive load and non-standard language input

E-mail addresses:

MA: [albm@zhaw.ch](mailto:albm@zhaw.ch)

MED: [ehre@zhaw.ch](mailto:ehre@zhaw.ch)

AHH: [huna@zhaw.ch](mailto:huna@zhaw.ch)

CL: [caroline.lehr@zhaw.ch](mailto:caroline.lehr@zhaw.ch)

MB: [michael.boos@uzh.ch](mailto:michael.boos@uzh.ch)

MK: [matthias.kobi@uzh.ch](mailto:matthias.kobi@uzh.ch)

LJ: [lutz.jaencke@uzh.ch](mailto:lutz.jaencke@uzh.ch)

SE: [s.elmer@psychologie.uzh.ch](mailto:s.elmer@psychologie.uzh.ch)

Correspondence to:

Stefan Elmer, Department of Psychology, Division Neuropsychology, University of Zurich, Binzmühlestrasse 14/25, 8050 Zurich, Switzerland

Michaela Albl-Mikasa, Institute of Translation and Interpreting, Zurich University of Applied Sciences (ZHAW), Theaterstrasse 15c, 8400 Winterthur, Switzerland

# **Cognitive Load in Relation to Non-Standard Language Input: Insights from Interpreting, Translation and Neuropsychology**

## **Abstract**

The linguistic, psychological, and neural processes underlying simultaneous interpreting and translation have attracted widespread interest in the scientific community. However, the cognitive load of these bilingual activities has hardly been explored, and the underlying behavioral and physiological mechanisms are still poorly understood. In this article, we describe a promising interdisciplinary and multimodal approach to assess the behavioral and physiological indices of cognitive load during interpreting and translation in laboratory and simulated workplace settings. In this context, we emphasize the importance of ecological validity and explain how comparisons between authentic non-standard input (i.e. ELF) and edited English versions of the same stimuli can be used to evaluate cognitive load while controlling for the general cognitive demands associated with interpreting and translation. The perspective we present in this article might pave the way for a clearer understanding of the multifaceted dimensions of cognitive load during simultaneous interpreting and translation as well as during the processing of ELF.

**Keywords:** simultaneous interpreting (SI), English as a lingua franca (ELF), cognitive load, mixed methods, EEG

## **1. Introduction**

Simultaneous interpreting (SI) is one of the most complex and demanding bilingual language processing tasks there is (Christoffels & de Groot 2005: 454). As such, it has sparked interest in linguists and neuropsychologists trying to gain insights into how different languages are processed in the bilingual mind and what functional and anatomic correlates underlie the control of multiple languages. For interpreting studies, cognitive processes, mental capacity management and the high cognitive demands placed on real-time language processing and transfer have been the focus of attention, with process research taking center-stage from the outset. By contrast, translation studies has only recently started to address issues concerning internal processes and decision-making in order to gain insights into how translation performance is affected by factors such as time pressure, information content or input quality

(Muñoz 2012). Despite this fundamental interest and the research effort into the human language processing apparatus by researchers in various disciplines, findings with regard to the cognitive load involved in SI, in particular, and the control of multiple languages, in general, have been somewhat restricted with respect to their explanatory power (Muñoz et al. 2019). Interpreting scholars in particular can be criticized for their use of less-than-objective measures with very small samples whereas neuropsychologists can be accused of confining their studies to laboratory settings with small linguistic units as stimuli, which do not take into account the real-life requirements and challenges of the interpreting task.

A recent societal development has introduced an additional challenge to interpreters' activity that can complicate bilingual processing and potentially increase their cognitive load.<sup>1</sup> Due to the global spread of English as a lingua franca (ELF), a growing volume of interpretation has to be provided for speeches that are given by non-native speakers of English (Albl-Mikasa 2017, 370). Judging from the critical attitude of many professional interpreters, ELF is perhaps not always the practical solution to multilingual communication problems that it is often assumed to be. Findings from the emerging study of ELF in relation to interpreting and translation (ITELF; Albl-Mikasa 2017) suggest that additional demand may be placed on interpreters' processing by non-standard English input.

It is against this background that the interdisciplinary team of the authors of this article decided to join forces to explore the possibilities offered by good practice from their respective disciplines in order to develop a new ecologically valid approach targeted at evaluating cognitive load during interpreting and translation.<sup>2</sup> The aims are multifold in that our research is designed to provide new insights into cognitive load in interpreting and translation as well as into the processing of non-standard input. First, the comparison between the linguistic processing of authentic ELF texts and their edited versions (edited English, or EdE) is introduced as a new, ecologically valid approach to measuring cognitive load. Secondly, comparisons between experts and non-experts performing interpreting and translation tasks can help to identify the influence of training and experience on the management of cognitive load. Finally, new insights are expected into the potential 'cost' of the processing of ELF input on the basis of multiple quantitative and qualitative measures.

---

<sup>1</sup> Unless indicated otherwise, 'interpreters' refers to professional simultaneous interpreters and 'translators' to professional translators.

<sup>2</sup> The project referred to in this article is called *Cognitive Load in Interpreting and Translation* (CLINT). More information can be found at <https://www.zhaw.ch/en/linguistics/institutes-centres/iued/research/clint/>

In order to provide a comprehensive assessment of cognitive load, a wide range of neuropsychological and process-related methods need to be applied in the laboratory or at the (simulated) workplace. In the present paper, we briefly outline the limited research in interpreting studies to date on cognitive load and the reason for this dearth (2). We then present a brief overview of neuropsychological results regarding cognitive control and mental load in SI (3). This is followed by preliminary pieces of evidence that point to ELF adding to interpreters' cognitive load (4). After setting the scene with this literature review, we describe the various methods applied in our research to measure cognitive load in interpreting, translation, and other multilingual tasks (5). We outline the advantages of our mixed-method interdisciplinary approach and propose using comparisons between ELF and EdE as a new ecologically valid approach to measuring cognitive load (6) before considering future directions (7).

## **2. Cognitive load in interpreting studies**

The construct 'cognitive load' refers to the demands placed on a person's working memory by (1) the main task that she is currently performing, (2) any other task(s) she may be performing concurrently and (3) distracting aspects of the situation in which she finds herself (Berthold & Jameson 1999). Due to limited working memory capacity, fundamental issues in SI include demands on working memory resources, task components involving effortful processes and processes requiring attention. SI is highly susceptible to cognitive overload because it involves parallel cognitive processes that have to be accomplished under extreme time pressure: attentive listening to the source language (SL) input, maintaining SL information in short-term memory, articulating the target language (TL) speech (and thereby deploying working memory and language switching), monitoring both the input and output languages (managing divided attention) and inhibiting articulation of the SL. Consequently, cognitive research into SI has almost always been an interdisciplinary effort drawing on findings from cognitive psychology.

At the same time, research explicitly addressing and measuring cognitive load in SI has been relatively scarce. There are only two models dealing explicitly with cognitive load, namely Gile's 'effort models' (1997; 1999) and Seeber's 'cognitive load model' (2011; Seeber & Kerzel 2012). Gile's effort models, which treat SI as the management of mental capacity, proceed from the assumption that interpreters work close to saturation and that cognitive

processing requirements, if they exceed the total capacity available, may lead to interpreting problems. According to Gile, the effort models of SI is a cognitive framework. It conceptualizes SI as a set of multiple cognitive operations which can be grouped into three (plus one) efforts (2008, 59). A conceptual framework, explanatory model and didactic tool, it is not geared towards prediction or testing, but rather illustrates how combinations of two or three efforts require more processing capacity than any effort alone (60). Of particular interest for our research with ELF is Gile's concept of "local cognitive load" (61), according to which cognitive load imported from processing the previous sentence and trying to formulate it in the TL may interfere with the processing of the next sentence. Such "imported cognitive load" (62) can be assumed to be of particular relevance for non-standard input or when the previous sentence causes ELF-induced comprehension difficulties.

Seeber's cognitive load model also focuses on the cognitive demands inherent in SI, but unlike Gile's efforts models also makes an attempt to quantify cognitive load, relying principally on Wickens' (1984) "demand vectors and conflict coefficients" (Seeber 2011, 189). According to Seeber, the cognitive load model accounts for the effects of different combinations of sub-tasks as well as different strategies for coping with syntactic asymmetries between the SL and TL and related changes in cognitive load. This has consequences, in particular, for "cognitive load management at the micro level" (190). Rather than working close to cognitive saturation most of the time, local cognitive resource demands may vary, because interpreters will find their way around local hurdles by developing ways and means to save processing capacity and reduce demands. At the same time, some strategies require more cognitive processing resources, so "the amount of cognitive load experienced by [simultaneous interpreters] might be causally related to the amount of restructuring they engage in" (197). Here, too, the application of micro-strategies modulating cognitive load is of relevance to our research. While for Seeber the latter assumption refers to SI between structurally asymmetrical language pairs, we see implications with regard to processing ELF in that this would suggest that the re-interpretation effort during non-standard input comprehension might add to cognitive load.

In order to measure local cognitive load, Seeber proposes cognitive pupillometry (i.e. mean pupil dilation). The first such study of the effect of directionality-contingent syntactic complexity on mental load by Tommola and Niemi (1986) was followed by studies that confirmed general interpreting wisdom, namely that SI is more demanding than shadowing,

shadowing is more load-intensive than listening comprehension (Hyönä et al. 1995) and that German verb-final structures are more taxing than German verb-initial structures and decontextualized sentences more demanding than contextualized ones (Seeber & Kerzer 2012). Nevertheless, Seeber (2013, 27) concludes that the method is inadequate for the quantification of average cognitive load across long stimuli and later that “one of the major challenges in applying the construct of cognitive load to research in interpreting has been the difficulty of measuring the phenomenon” (Seeber 2015, 61). Thus, while there may be advantages in such psychophysiological measures as pupillometry over performance measures, they cannot provide the full picture. Expanding the repertoire of methods in interpreting research may be a way to address this shortcoming, as discussed in the next section.

### **3. Overview of neuropsychological studies on cognitive control in interpreters**

With the advent of neuroimaging techniques, research has moved toward a better understanding of how multiple languages are represented and controlled in the brain, and initial studies on bilinguals provided evidence for common neural networks underlying the representation of multiple languages (Perani & Abutalebi 2005). Currently, there is little doubt that cognitive control is needed by multilinguals for various functions such as selecting which language to use (Abutalebi & Green 2007; Rodriguez-Fornells et al. 2006), avoiding negative transfer between different language systems, inhibiting the non-target language (Rodriguez-Fornells et al. 2002), and switching between languages (Garbin et al. 2011; Price 2012). The brain regions supporting cognitive control in bilingual individuals have been described in detail (Abutalebi & Green 2007; Rodriguez-Fornells et al. 2006), and numerous studies have identified the prefrontal cortex (PFC), caudate nuclei (CN), middle-anterior cingulate cortex (aCC), and inferior parietal lobule (IPL) as key regions of the language-control network (Figure 1). Nevertheless, the exact influence of bilingualism and multilingual experience on cognitive and executive functions remains unclear (Lehtonen et al. 2018; Paap et al. 2015). The neuroimaging studies in the next section provide some insight into the possible relationship in the context of SI.

---

INSERT FIGURE 1 ABOUT HERE

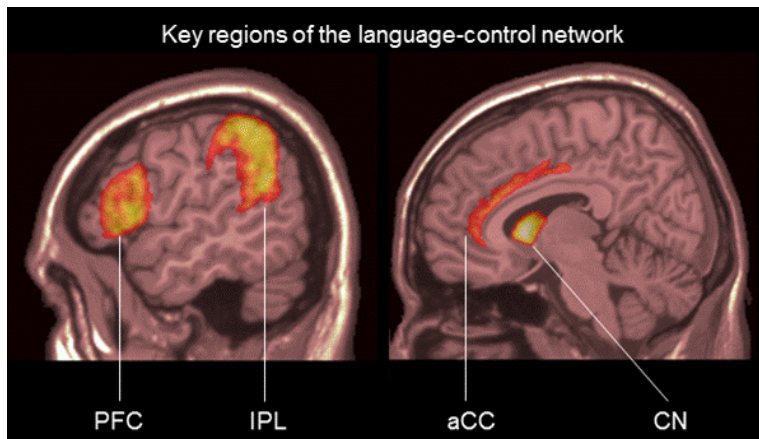


Figure 1. Schematic illustration (lateral view) of brain regions that have been identified as essential for cognitive control in multilinguals. PFC = prefrontal cortex; IPL = inferior parietal lobule; aCC = anterior cingulate cortex; CN = caudate nuclei.

### 3.1. Functional neuroimaging studies

SI is generally accepted to be cognitively more demanding than other types of language control, which has prompted an interest in elucidating its functional underpinnings. In one of the first neuroimaging studies, Rinne and colleagues (2000) measured cerebral blood flow in a sample of professional interpreters and compared brain activity induced by SI and shadowing. Results revealed that SI resulted in increased brain activity in left-hemispheric fronto-temporal brain regions related to lexical-semantic processing, verbal working memory, and executive functions, including Broca's area, the dorsolateral PFC, the premotor cortex, and the inferior temporal gyrus. Moreover, the researchers recognized that interpreting into the non-native language (L2) elicited more extensive activation patterns, suggesting increased cognitive load during L1-L2 compared to L2-L1 interpreting. Using functional magnetic resonance imaging (fMRI), Elmer (2016) compared the within-group and single-subject differences in a small sample of interpreters who interpreted or repeated (shadowed) simple sentences with a subject-verb-object (SVO) structure. Analyses based on regions of interest showed that during L2-L1 interpreting (Broca) pars triangularis was commonly activated across participants, whereas the other brain regions of the language-control network (aCC, IPL, CN) demonstrated higher inter-individual variability for both directions. Hervais-Adelman et al. (2015) evaluated training-related functional changes in a group of trainee interpreters undergoing a fifteen-month program. After the program, the trainees generally showed decreased brain activity during SI in a network consisting of brain regions that are not essentially related to functions. This network included the right aCC, left precentral

gyrus, left postcentral gyrus, right CN, and left inferior frontal gyrus. These results might indicate lower demands on explicit language-control mechanisms as the interpreting task became more automatized.

A few neuroimaging studies have also evaluated executive functions and resting states in interpreters compared to translators or other multilinguals (Becker et al. 2016; Elmer et al. 2011a; Van de Putte et al. 2018). For example, Becker et al. (2016) evaluated the functional correlates underlying task switching and dual task performance in interpreters and translators. The interpreters exhibited lower mixing costs in task-switching and demonstrated a dual-task advantage. Furthermore, they evinced higher resting-state connectivity between the left frontal pole, inferior frontal gyrus, and middle temporal gyrus. Van de Putte et al. (2018) compared brain activity between matched groups of interpreting and translation students during a Simon task and a color-shape switching task before and after nine months of training. After training, the interpreting students showed higher activity in the left superior temporal gyrus during the Simon task as well as in the right angular gyrus during the switching task. However, since the two groups did not differ in terms of behavioral performance and the imaging data were not corrected for multiple comparisons, results should be interpreted with caution.

### ***3.2. Structural neuroimaging studies***

In the last few years, neuropsychological research with interpreters has also focused on the evaluation of grey and white matter parameters in brain regions related to cognitive control mechanisms and linguistic functions (Becker et al. 2016; Elmer et al. 2011b; 2014; 2019; Hervais-Adelman et al. 2017; Van de Putte et al. 2018). This perspective is rooted in the notion that the specific cognitive and linguistic skills necessary for translating a SL into a TL under extreme time constraints are acquired only in adulthood. Using a cross-sectional approach, Elmer and colleagues (2014) consistently found reduced grey matter volume in interpreters compared to multilingual controls in regions of the language-control network, including the left aCC, bilateral pars triangularis, left pars opercularis and the left supramarginal gyrus. Since grey matter volume in the aCC, left pars triangularis, right pars opercularis, and bilateral caudate nuclei was negatively correlated with the cumulative number of interpreting hours, results suggest practice-related anatomical changes. Another cross-sectional study (Becker et al. 2016) found higher rather than lower grey matter volume in interpreters compared to controls in the left frontal pole. Furthermore, interpreters



exhibited less mixing costs in a task-switching paradigm, and this behavioral index was negatively related to grey matter volume in the frontal pole area. Using a longitudinal approach, Hervais-Adelman et al. (2017) evaluated cortical thickness in a group of SI trainees before and after training and compared this parameter to multilingual participants scanned over a similar time interval. After SI training, the participants exhibited increased cortical thickness in the left posterior superior temporal gyrus, supramarginal gyrus, planum temporale as well as in the right angular gyrus, dorsal premotor cortex and parietal lobule. The results concerning grey matter in interpreters and SI trainees seem somewhat contradictory, but it may be that grey matter plasticity follows a linear or possibly an inverse U-shaped devolution as a function of training and experience (Elmer et al. 2014).

Fewer studies have focused on the white matter pathways subserving SI and contributing to cognitive control. In their cross-sectional study, Elmer et al. (2011b) evaluated whole-brain white matter integrity between interpreters and multilingual controls and discovered between-group differences in the white matter underlying brain regions involved in cognitive control, articulation, and auditory-motor transformations. In the study mentioned previously, Van de Putte et al. (2018) also compared structural connectivity in interpreting and translation students before and after nine months of training. Their main finding was increased training-related structural connectivity in interpreting students in two language-control networks. Taken together, the results of these few pioneer studies point to a relationship between interpreting training and anatomical features of brain regions subserving language processing and cognitive control mechanisms. Longitudinal studies with larger samples, different age cohorts, and different levels of SI experience would certainly shed more light into this relatively under-researched area.

### ***3.3. Electrophysiological studies***

Several electrophysiological (i.e. EEG) studies have tried to (indirectly) measure indices of cognitive load during intra- and interlingual language processing tasks such as SI. In 1993, Petsche and colleagues conducted the first study of this type and measured brain activity in three interpreters while they mentally interpreted sentences from L1 into L2 or from L2 into L1. Although there was a high degree of inter-individual variability, interpreting was generally associated with prominent beta activity at temporal electrodes. In addition, the comparison between the two interpreting directions yielded increased beta coherence at right-hemispheric electrodes, possibly reflecting higher cognitive load in the L1-L2 direction. In a

subsequent study, Grabner et al. (2007) evaluated event-related synchronization (ERS) and desynchronization (ERD) patterns in a sample of 13 translation and interpreting (T&I) students while they were exposed to visually-presented high and low frequency English words that had to be translated into German. Results revealed higher ERS in the theta frequency band at the parietal electrodes as well as increased alpha ERD at frontal scalp sites during the translation of low as compared to high frequency words. Since alpha negatively correlates with brain activity (Laufs et al. 2003; Oakes et al. 2004), alpha ERD over frontal electrodes and theta ERS at parietal scalp sites might reflect a higher engagement of fronto-parietal networks while processing the linguistically more demanding low-frequency items. In addition, ERD in the alpha band and over the left hemisphere was higher for successfully translated compared to untranslated low-frequency words, indicating a sensitivity of the alpha band to lexical-semantic processes.

More recently, Klein et al. (2018) evaluated EEG-based resting-state functional connectivity in the source-space in a sample of interpreters and multilingual controls using a graph-theoretical approach. The research team noted interhemispheric hyperconnectivity in the alpha frequency band between the ventral part of the prefrontal cortex (pars opercularis and pars triangularis) and the dorsolateral PFC in interpreters. Although the data were collected during a task-free condition, this functional finding might reflect a reconfiguration of frontal neural circuits involved in modulating cognitive control during interpreting. In summary, the handful of EEG studies that have evaluated language processing in interpreters placed under different cognitive and linguistic demands report somewhat incongruent results. They also differed in terms of paradigms, data analyses, and the EEG parameters used to operationalize language-related processing demands and cognitive load, usually relying on small linguistic units as stimuli and tasks only vaguely related to SI. There is a clear need to develop new approaches that enable us to measure cognitive load during SI in a more specific, standardized, and ecologically valid fashion. Before details are provided about such an approach, the next section explains why ELF is a particularly interesting phenomenon in this context.

#### **4. Evidence pointing to ELF adding to interpreters' cognitive load**

The point of departure for our interdisciplinary research is the assumption that today's reality of millions of people communicating in a language that is not their first, namely English, comes with a cost. The emphasis of ELF research until recently has been on communicative

effectiveness in conversational situations. However, interpreting and translation researchers have started to look into the impact of ELF on mediated communication in non-interactive settings where meaning negotiation principles do not apply (cf. Albl-Mikasa & Ehrensberger-Dow 2019). Investigation of ELF in relation to interpreting and translation (i.e. ITELf) had been triggered by the critical attitudes on the part of interpreters regarding ELF speaker input at international events. The ensuing research efforts have picked up over the past ten years, and preliminary results suggest that ELF induces additional cognitive load. This might explain interpreters' reports of their job becoming increasingly more strenuous, tiresome, and unsatisfying (Albl-Mikasa 2010, 142).

In one of the first surveys on ELF in relation to interpreting, the adverse effects of non-native English speaker input on interpreters' capacity management was emphasized (Albl-Mikasa 2010). Interpreters explicitly mentioned that higher levels of concentration, additional effort, and extra processing were required in the comprehension phase for more attentive listening, disambiguation, reformulations, deriving intended meaning from non-standard English, recovering incomplete structures, ironing out mistakes and irregularities as well as unravelling unusual word combinations (136). When interpreting for (rather than from) ELF speakers, adjustments to the assumed lower proficiency levels of the audience also involved additional cognitive load in terms of paying greater attention to carefully selecting expressions or avoiding idiomatic phrases, reducing syntactic or lexical complexity and explaining unusual wordings, all of which was found to interfere with "long-established automatisms" (138).

Automatization is, of course, at the core of reducing interpreters' workload. Fundamental SI processes such as inferencing and anticipation depend on it. Destabilization of automatized processes was also found in a small-scale study involving three ELF speakers and a student interpreter and retrospective interviews with both the ELF speakers and the interpreter (Albl-Mikasa 2013a). The findings suggested that retrieval of established transfer routines and translation equivalent links was impeded. An explanation was sought in van Dijk and Kintsch's (1983, 334) "principle of encoding specificity". According to them, activation depends on a match of incoming items (from the speaker) with previously encoded items (by the listener). Input deviating from the learned standard will lead to a mismatch requiring additional effort in order to be resolved. This phenomenon could be at the root of interpreters' complaints that ELF acts as a "brain stopper" (Albl-Mikasa 2014a, 23).

Other small-scale studies have pointed to the following ELF-related factors that may increase cognitive load: (1) foreign accents (Sabatini 2000; McAllister 2000; Cheung 2003; Kurz 2008), (2) unconventional and incomplete structures, unusual lexical expressions or logical irregularities (Albl-Mikasa 2010, 2013a), (3) crosslinguistic transfer from ELF speakers' first languages (Albl-Mikasa 2014b), (4) lack of a "shared languages benefit" and interpreters not having the ELF speaker's L1 in their working languages repertoire (Albl-Mikasa 2013b), (5) text organization and restricted application of text development and audience design conventions (Albl-Mikasa et al. 2017a), (6) lack of express-ability as well as restricted pragmatic fluency and means of expression to make intentions, purposes, and objectives explicit (Albl-Mikasa 2013b), (7) register shifts (Albl-Mikasa 2017) and (8) low proficiency levels (Albl-Mikasa 2014b).

The above-mentioned studies have consolidated the assumption that it is not necessarily each of the listed factors by itself that might induce cognitive load, but that it is often the combination of such factors that taxes interpreters' resources when interpreting ELF speakers. Even though English native speakers' presentation rates are often faster, interpreters seem to cope better with the formers' input than with non-standard input (Albl-Mikasa et al. 2017a). The underlying reason is that interpreters have to enter into capacity-consuming normalization and compensation processes to recover intended meaning and sometimes to tease out exactly what the ELF speakers are trying to say. Relevant research into such potential additional cognitive load is limited and preliminary in nature and, as with the studies mentioned above, based primarily on self-report data.

The same is true for translation of written ELF, where even less research has been conducted so far. In one of the few performance-based studies to date (Albl-Mikasa et al. 2017b), the effect of ELF texts on translators was investigated on the basis of ELF source texts and their edited versions after revision by the European Parliament's editing unit. After an in-depth analysis of the twelve unedited and edited texts, three of each were translated by six professional translators. The segments in the ELF source texts selected for modification by the editing unit gave rise to translation problems in twice as many cases as the edited counterparts. The study also showed that the majority of problems could be traced to the non-standard use of lexical expressions. Finally, screen recordings indicated that more time was required for the translation of the ELF texts. As suggested from this overview, the findings

from the limited research available make it plausible to assume that processing ELF involves additional cognitive load for T&I practitioners. However, more robust empirical results from larger-scale investigations are necessary to substantiate this claim.

## **5. Measuring cognitive load in language processing**

Cognitive load is a multifaceted theoretical construct composed of many intertwined factors. Increased load can be assumed to manifest itself in subjective feelings of stress, working memory burdens, behavioral changes, and physiological responses. Accordingly, the most convincing way to capture these various dimensions is to use a multimodal, mixed method approach that includes a variety of measures to assess cognitive load during language processing. Chen et al. (2012) have divided these measures into different categories: subjective, physiological, behavioral, and performance measures. In our current research, we are assessing cognitive load in a comprehensive way with measures covering all the categories, combined in a complementary fashion to elucidate the phenomenon from different angles in two different settings, namely a simulated workplace and a neuropsychology lab setting, as explained below.

### ***5.1. Simulated workplace setting***

Interpreting and translation take place in such a wide variety of settings that it is difficult to simulate them accurately, but it is possible to approach ecological validity by providing mock-ups of conference booths for SI and computer workplaces with access to online resources for translation activities. In the simulated workplace setting, the focus is on assessing subjective, behavioral, and performance measures of processing ELF input in naturalistic tasks appropriate to the background and experience of the respective participant. Specifically, the BA students who have experience producing spoken target texts from other-language source texts but no experience with SI do sight interpretations of ELF and EdE texts whereas interpreters and MA interpreting students perform SI of ELF and EdE speeches (middle of Figure 2). Translators and students specializing in translation produce target texts in their L1 from ELF and EdE source texts (left side of Figure 2). Finally, multilingual controls matched with respect to experience level (e.g. professional, MA or BA student) perform listening and reading comprehension tasks for ELF and EdE speeches and texts (right side of Figure 2).

-----  
INSERT FIGURE 2 ABOUT HERE

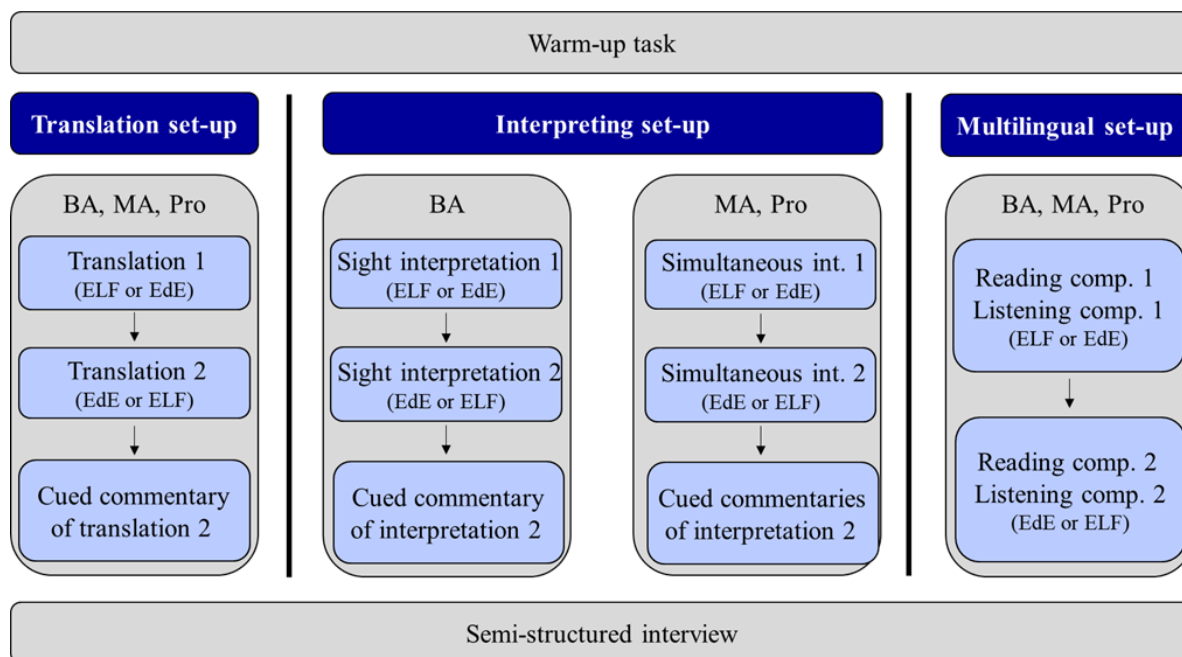


Figure 2. Design for the simulated workplace setting.

In our project, subjective measures of cognitive load include the participants' accounts of their cognitive involvement in the cued retrospective commentaries and interviews, as well as their ratings of stress immediately after each task (i.e. STAI). Complementing subjective assessments, physiological correlates of cognitive load provide a more objective indication of the amount of cognitive capacity devoted to performing a particular task. A physiological measure that has been identified as related to cognitive load is pupil dilation (see Section 2). Although there has been criticism of its validity, since pupil size is known to be sensitive to many factors apart from cognitive activity (O'Brien 2010, 253), it might provide information about processing ELF. Eye-tracking is therefore used in both the interpreting and the translation tasks. Heart rate is another physiological measure being taken, since it has been identified as an indicator of stress during SI (Mackintosh 2002; Korpala 2017).

When studying translation and reading processes, gaze patterns from eye tracking have proven to be very useful behavioral measures, especially when triangulated with computer logging and screen recordings, to gain information on activities such as reading, writing, revising, pausing, and information searching (Hvelplund 2017). In our project, these measures can allow us to understand which parts of the ELF and EdE texts require increased

attention and what strategies are used by translators to solve problems related to cognitive load. Another behavior that we are investigating as an indicator of cognitive load in both interpreting and translation is gesturing (cf. Goldin-Meadow et al. 2001). Facial expressions may reveal negative emotions and stress related to the cognitive resources required by a language processing task (cf. Lerner et al. 2007) and are also being analyzed on the basis of video recordings taken during the tasks carried out in the workplace setting.

In addition, assessments of interpreting or translation performance can provide information about the cognitive capacities occupied by the respective task. Performance measures are related to accuracy, appropriateness, and speed in producing the oral or written target text. With regard to SI, researchers have claimed that disfluencies, including filled and silent pauses, repetitions, repairs, drawn-out syllables and false starts are associated with production difficulties that might be related to cognitive load (Chen et al. 2012; Plevoets & Defrancq 2016). Similarly, the location of pauses or changes in pause patterns may be indicators of cognitive load during translation (Kruger 2016). The overall quality of the target texts, which can be assessed through subjective evaluations by experts or potential users may also be indicative of the cognitive load generated by processing ELF.

It must be stressed that virtually all available measures of cognitive load are only indirect indicators. In educational psychology, where cognitive load theory originated (Sweller et al. 1998) and as it is understood in cognitive interpreting and translation studies, it is acknowledged that cognitive load can only be inferred by observing how people actually perform tasks. This indirectness of measures provides the motivation and necessity for triangulating methods, data, and results, all of which are integral to our interdisciplinary approach.

## ***5.2. Neuropsychology lab setting***

The main motivation for also carrying out tests in the controlled setting of the neuropsychology lab is to take objective physiological measures of cognitive load during the processing of written and spoken ELF and EdE texts. In particular, the theta/alpha ratio detectable with EEG combines two different workload estimates (Gevins et al. 1997) and is considered to be more sensitive than separate measures of frontal theta and parietal alpha power (Holm et al. 2009). Accordingly, experiments focusing on language and cognitive processing during spoken-language or written-language tasks were designed for our project

(Figure 3). Both experiments consist of three main tasks: an input control task (reading or listening), an output control task (copying or shadowing) as well as an interlingual task (translating or interpreting). Two different texts are used in each experiment, one of which is presented in the ELF and the other in the EdE version (abstract 1 & 2 for the written-language experiment and speech I & II for the spoken-language experiment). The assignment of texts, conditions, and order of texts are randomized as indicated by the arrows in Figure 3.

-----  
 INSERT FIGURE 3 ABOUT HERE  
 -----

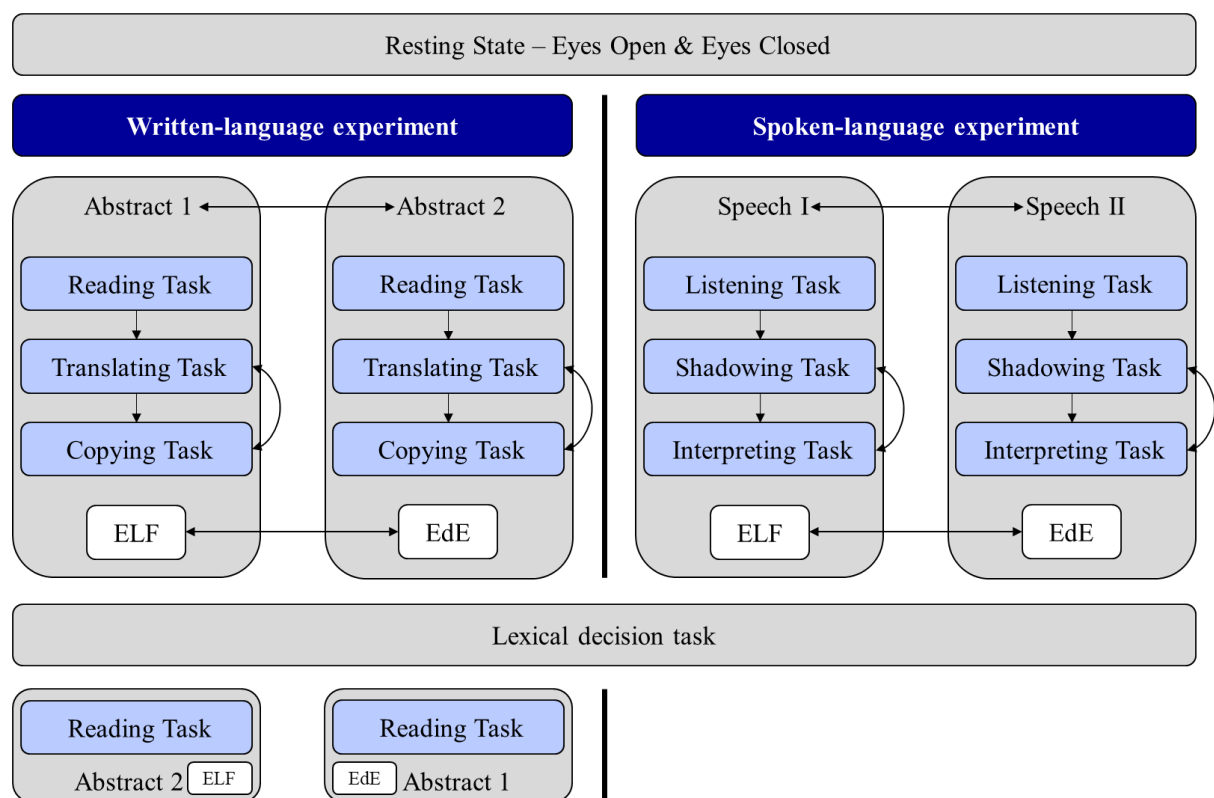


Figure 3. Experimental settings for the written-language and spoken-language tasks.

These experimental procedures rely on within-group comparisons to assess cognitive load induced by ELF and language tasks of various levels of complexity. Interpreters and MA and BA students specializing in interpreting participate in the spoken-language experiment whereas translators and students specializing in translation participate in the written-language experiment. Multilingual controls with similar levels of experience are randomly assigned to one or the other experiment.



The spoken language experiment (right side of Figure 3) consists of three tasks, namely listening, shadowing, and interpreting. During the listening task, participants are exposed to aurally-presented ELF and EdE speeches and afterwards answer short visually-presented content questions (three-alternative forced-choice task) to assess listening comprehension. The purpose of this task is twofold. First, it serves as an exposure component to assess cognitive load while listening to ELF compared to EdE speeches. Second, it can be used as an input control condition to disentangle cognitive load induced by listening to spoken ELF vs. interpreting ELF. In the shadowing task, participants have to repeat sections of the ELF and EdE speeches. Furthermore, covert shadowing (silent) will be alternated with short periods of overt shadowing (aloud) to monitor performance. This task is supposed to further increase cognitive load and also acts as a speech output control condition. Finally, the ELF and EdE interpreting task (alternately overt and covert) is expected to generate the highest cognitive load.

Similar to the spoken-language experiment, the written-language experiment (left side of Figure 3) consists of three different tasks and includes an input and output control condition. In the reading task, participants have to read an ELF or EdE abstract and respond to visually presented questions to assess reading comprehension. In order to simulate a natural reading condition, participants can control the reading speed by pressing a response button to see the next sentence. Afterwards, participants have to either copy or translate each source text sentence within a fixed time window of six minutes. The sentence-by-sentence presentation is an adaptation of that in CAT tools, which can be assumed to be familiar to translation professionals and students. The copying task serves as a control condition to assess brain activity related to motor preparation and output. In addition, this task is assumed to be between reading and translating with respect to cognitive load. In the translating task, the process of L2-L1 translation is added to the participants' cognitive workload. After a lexical decision task targeted at evaluating intra- and interlingual language processing as a function of expertise, the same abstracts are presented again but in the other version (EdE or ELF). This procedure captures reading-related indices of cognitive load using the same text material. During all tasks in the written-language experiment, eye-tracking measurements are also taken to assess differences in pupil dilation, fixation duration, number of fixations, and regressions related to processing ELF.

Heart rate (HR) and galvanic skin response (GSR) measurements round off the multifaceted picture of cognitive load while processing ELF and EdE texts and tasks of increased complexity in the lab. Since a shorter inter-beat interval (IBI) has been shown to go hand in hand with higher cognitive demands (Fairclough et al. 2005), we predict a linear IBI decrease from the interpreting/translating to the shadowing/copying and listening/reading tasks. Furthermore, in each task IBI is expected to be shorter while processing ELF compared to EdE texts. Finally, based on findings that workload is associated with higher GSR (Muhl et al. 2014), we predict a parametric increase in GSR across the three types of task as well as higher GSR values while processing ELF compared to EdE texts.

## **6. An interdisciplinary approach to investigating cognitive load**

As reviewed in the previous sections, studies on SI and translation have attempted to characterize the situative, personal, and psychological variables influencing cognitive load. Neuroimaging and electrophysiological studies have provided insights into the neural architecture of cognitive control and contributed to identifying markers of cognitive load in different linguistic tasks. However, most of the published studies in this domain are characterized by small samples, non-naturalistic settings, stimuli that do not reflect the complexity of authentic input, and a failure to consider different levels of expertise (Muñoz et al. 2019). Drawing on this background, we envisage a way forward to doing research that focuses on the manifold manifestations of cognitive load during interpreting and translation under more ecologically valid conditions.

In our research, we are focusing on how interpreters and translators deal with non-standard input (i.e. ELF), since the ubiquitous use of English by non-native speakers has become a reality in many of their professional lives. Since ELF deviates in many ways from standard English input that can affect comprehensibility, T&I professionals are faced with additional cognitive challenges that go beyond the usual demands of interpreting or translation. The direct comparison between authentic ELF and the respective EdE versions thus allows us to keep the task constant (i.e. the same interpreting/translating task and language direction) and to tease apart cognitive load induced by ELF from the general cognitive requirements associated with interpreting and translation *per se*. This counteracts a main drawback of previous neuropsychological studies on SI and translation that indirectly assessed cognitive load and language-control mechanisms by comparing experimental conditions that varied on multiple dimensions.

Another important aspect of our interdisciplinary research is the inclusion of participants who differ in T&I expertise, namely professional interpreters and translators, students in interpreting or translation programs, and multilingual controls such as teachers or writers and language or education students. With respect to the relationship between T&I expertise and ELF-induced cognitive load, we expect that the higher the degree of specific skills acquired to master interpreting and translation, the more differentiated the influence of ELF on cognitive load will be. Since participants who are not trained in SI and translation are generally overwhelmed by such tasks, direct comparisons between the T&I and multilingual groups make little sense for those and are not planned. However, intra-group comparisons between the multilinguals will allow us to draw conclusions about how non-professionals deal with ELF input.

The combination of simulated workplace and laboratory settings in our research is an attempt to overcome the specific advantages and disadvantages of each. The laboratory setting enables us to collect objective data of cognitive load, including brain activity, heart rate, GSR, eye movements, and different behavioral measures while controlling for other variables. The main disadvantage of laboratory settings for our purposes is its reduced ecological validity, which seriously limits any generalizations to T&I practice. The new approach taken here in using larger text units from authentic material is a major step in the direction of increasing ecological validity in laboratory settings. Workplace settings have the benefit of simulating real-life conditions in that coherent texts can be used as stimuli for realistic T&I tasks whose processes can be captured with relatively non-intrusive techniques. However, the drawbacks are the increased likelihood of contamination by confounding variables that cannot be controlled and the incompatibility of using more complex techniques such as EEG and GSR. Causal relationships are thus more difficult to determine, mainly due to the manifold variables that exist in real-life environments. By triangulating the findings from the same participants recorded doing tasks in both settings, we expect to gain important insights not only into T&I processes but also the multilingual mind.

## **7. Implications and future directions**

The framework presented in this article relies on an interdisciplinary, mixed-method, multimodal approach to systematically assessing cognitive load during interpreting and translation in laboratory and workplace settings. This approach is anchored in the comparison

between processing ELF and EdE in various authentic and controlled tasks and might serve as a promising way forward in determining the subjective, behavioral, and physiological correlates of additional cognitive load, while controlling for the influence of load generally related to interpreting or translation. Our approach is informed by good practice in our respective disciplines and has developed and benefited from reciprocal input. This article is intended to serve as both a theoretical and a practical framework for others studying the multiple dimensions of cognitive load in interpreting, translation, and related fields, and to contribute to advancing future research on this fascinating topic.

## Acknowledgments

This research has been supported by the Swiss National Science Foundation (SNSF, Sinergia grant CRSII5\_173694). The authors declare no competing interests.

## References

- Abutalebi, Jubin, and David Green. 2007. "Bilingual Language Production: The Neurocognition of Language Representation and Control." *Journal of Neurolinguistics* 20 (3): 242–275. doi:10.1016/j.jneuroling.2006.10.003
- Albl-Mikasa, Michaela. 2010. "Global English and English as a Lingua Franca (ELF): Implications for the Interpreting Profession." *Trans-Kom* 3 (2): 126–148.
- Albl-Mikasa, Michaela. 2013a. "ELF Speakers' Restricted Power of Expression – Implications for Interpreters' Processing." *Describing Cognitive Processes in Translation. Special Issue of Translation and Interpreting Studies (TIS)* 8 (2): 191–210.
- Albl-Mikasa, Michaela. 2013b. "Express-ability in ELF Communication." *Journal of English as a Lingua Franca* 2 (1): 101–122.
- Albl-Mikasa, Michaela. 2014a. "English as a Lingua Franca in International Conferences - Current and Future Developments in Interpreting Studies." *Interpreting and Translation Studies (Korea)* 18 (3): 17–42.
- Albl-Mikasa, Michaela. 2014b. "The Imaginary Invalid. Conference Interpreters and English as a Lingua Franca." *International Journal of Applied Linguistics* 24 (3): 293–311.
- Albl-Mikasa, Michaela. 2017. "ELF and Translation/Interpreting." In *The Routledge Handbook of English as a Lingua Franca*, edited by Jennifer Jenkins, Will Baker, and Martin Dewey, 369–383. London: Routledge.
- Albl-Mikasa, Michaela, and Maureen Ehrensberger-Dow. 2019. "ITELF: (E)merging Interests in Interpreting and Translation Studies." In *Translation and Interpreting. Convergence, Contact, Interaction*, edited by Paola Gentile, and Eugenia dal Fovo, 45–62. Oxford: Peter Lang.
- Albl-Mikasa, Michaela, Sandra Guggisberg, and Fenja Luise Talirz. 2017a. "(Source)texting ELF - Native and Non-native English Speaker Discourse Production and Conference Interpreters' Preference for the Native Speaker." In *Translation Studies and Translation Practice*, edited by Lew Zybatow, Andy Stauder, and Michael Ustaszewski, 267–275. Frankfurt am Main: Peter Lang.

- Albl-Mikasa, Michaela, Giovanna Fontana, Laura Maria Fuchs, Lena Meret Stüdeli, and Aline Zaugg. 2017b. "Professional Translations of Non-native English: Before and After Texts from the European Parliament's Editing Unit." *The Translator* 23 (4): 371–387.
- Becker, Maxi, Torsten Schubert, Tilo Strobach, Jürgen Gallinat, and Simone Kuhn. 2016. "Simultaneous Interpreters vs. Professional Multilingual Controls: Group Differences in Cognitive Control as Well as Brain Structure and Function." *Neuroimage* 134: 250–260. doi:10.1016/j.neuroimage.2016.03.079
- Berthold, André, and Jameson, Anthony. 1999. "Interpreting Symptoms of Cognitive Load in Speech Input." In *User Modeling: Proceedings of the Seventh International Conference (UM99)*, edited by Judy Kay, 235–244. New York: Springer.
- Chen, Fang, Natalie Ruiz, Eric Choi, Julien Epps, M. Asif Khawaja, Ronnie Taib, Bo Yin, and Yang Wang. 2012. "Multimodal Behaviour and Interaction as Indicators of Cognitive Load." *ACM Transactions on Interactive Intelligent Systems (TiiS)* 2 (4): Article 22.
- Cheung, A. 2003. "Does Accent Matter? The Impact of Accent in Simultaneous Interpretation into Mandarin and Cantonese on Perceived Performance Quality and Listener Satisfaction Level." In *Evaluación de la calidad en interpretación de conferencias: investigación*, edited by Ángela. Collados Aís, María Manuela Fernández Sánchez, and Daniel Gile, 85–96. Granada: Editorial Comares.
- Christoffels, Ingrid K., and Annette M. B. De Groot. 2005. "Simultaneous Interpreting: A Cognitive Perspective." In *Handbook of Bilingualism: Psycholinguistic Approaches*, edited by Judith F. Kroll, and Annette M. B. De Groot, 454–479. New York: Oxford University Press.
- Elmer, Stefan. 2016. "Broca Pars Triangularis Constitutes a 'Hub' of the Language-Control Network during Simultaneous Language Translation." *Frontiers in Human Neuroscience* 10 (491). doi:ARTN 49110.3389/fnhum.2016.00491
- Elmer, Stefan, Jürgen Hanggi, and Lutz Jancke. 2014. "Processing Demands upon Cognitive, Linguistic, and Articulatory Functions Promote Grey Matter Plasticity in the Adult Multilingual Brain: Insights from Simultaneous Interpreters." *Cortex* 54: 179–189. doi:10.1016/j.cortex.2014.02.014
- Elmer, Stefan, Jürgen Hanggi, Martin Meyer, and Lutz Jancke. 2011b. "Differential Language Expertise Related to White Matter Architecture in Regions Subservicing Sensory-Motor Coupling, Articulation, and Interhemispheric Transfer." *Human Brain Mapping* 32 (12): 2064–2074. doi:10.1002/hbm.21169
- Elmer, Stefan, Jürgen Hanggi, Lucia Vaquero, Guillem Olivé Cadena, Clément Francois, and Antoni Rodriguez-Fornells. 2019. "Tracking the Microstructural Properties of the Main White Matter Pathways underlying Speech Processing in Simultaneous Interpreters." *Neuroimage* 191: 518–528. doi:10.1016/j.neuroimage.2019.02.056
- Elmer, Stefan, Martin Meyer, Lucas Marrama, and Lutz Jancke. 2011a. "Intensive Language Training and Attention Modulate the Involvement of Fronto-parietal Regions during a Non-verbal Auditory Discrimination Task." *European Journal of Neuroscience* 34 (1): 165–175. doi:10.1111/j.1460-9568.2011.07728.x
- Fairclough, Stephen H., Louise Venables, and Andrew Tattersall. 2005. "The Influence of Task Demand and Learning on the Psychophysiological Response." *International Journal of Psychophysiology* 56 (2): 171–184. doi:10.1016/j.ijpsycho.2004.11.003
- Garbin, G., A. Costa, A. Sanjuan, C. Forn, A. Rodriguez-Pujadas, N. Ventura, V. Belloch, M. Hernandez, and C. Avila. 2011. "Neural Bases of Language Switching in High and Early Proficient Bilinguals." *Brain and Language* 119 (3): 129–135. doi:10.1016/j.bandl.2011.03.011
- Gevins, Alan, Michael E. Smith, Linda McEvoy, and Daphne Yu. 1997. "High-resolution EEG Mapping of Cortical Activation Related to Working Memory: Effects of Task

- Difficulty, Type of Processing, and Practice.” *Cerebral Cortex* 7 (4): 374–385. doi:DOI 10.1093/cercor/7.4.374
- Gile, Daniel. 1997. “Conference Interpreting as a Cognitive Management Problem.” In *Cognitive Processes in Translation and Interpreting*, edited by Joseph H. Danks, Gregory M. Shreve, Stephen B. Fountain, and Michael K. McBeath, 196–214. London: Sage Publications.
- Gile, Daniel. 1999. “Testing the Effort Models’ Tightrope Hypothesis in Simultaneous Interpreting - A Contribution.” *Hermes* 23: 153–172.
- Gile, Daniel. 2008. “Local Cognitive Load in Simultaneous Interpreting and its Implications for Empirical Research.” *Forum* 6 (2): 59–77
- Goldin-Meadow, Susan, Howard Nusbaum, Spencer D. Kelly, and Susan Wagner. 2001. “Explaining Math: Gesturing Lightens the Load.” *Psychological Science* 12 (6): 516–522.
- Grabner, Roland H., Clemens Brunner, Robert Leeb, Christa Neuper, and Gert Pfurtscheller. 2007. “Event-related EEG theta and alpha Band Oscillatory Responses during Language Translation.” *Brain Research Bulletin* 72 (1): 57–65. doi:10.1016/j.brainresbull.2007.01.001
- Hervais-Adelman, Alexis, Barbara Moser-Mercer, and Narly Golestani. 2015. “Brain Functional Plasticity Associated with the Emergence of Expertise in Extreme Language Control.” *Neuroimage* 114: 264–274. doi:10.1016/j.neuroimage.2015.03.072
- Hervais-Adelman, Alexis, Barbara Moser-Mercer, Micah M. Murray, and Narly Golestani. 2017. “Cortical Thickness Increases after Simultaneous Interpretation Training.” *Neuropsychologia* 98: 212–219. doi:10.1016/j.neuropsychologia.2017.01.008
- Holm, Anu, Kristian Lukander, Jussi Korpela, Mikael Sallinen, and Kiti M. Muller. 2009. “Estimating Brain Load from the EEG.” *The Scientific World Journal* 9: 639–651. doi:10.1100/tsw.2009.83
- Hvelplund, Kristian T. 2017. “Translators’ Use of Digital Resources during Translation.” *HERMES - Journal of Language and Communication in Business* 56: 71–87. <https://doi.org/10.7146/hjlc.v0i56.97205>
- Hyönä, Jukka, Jorma Tömmola, and Anna-Mari Alaja. 1995. “Pupil Dilation as a Measure of Processing Load in Simultaneous Interpretation and Other Language Tasks.” *The Quarterly Journal of Experimental Psychology* 48A (3): 598–612.
- Klein, Carina, Silvana Iris Metz, Stefan Elmer, and Lutz Jancke. 2018. “The Interpreter’s Brain during Rest - Hyperconnectivity in the Frontal Lobe.” *Plos One* 13 (8). doi:ARTN e020260010.1371/journal.pone.0202600
- Korpala, Paweł. 2017. *Linguistic and Psychological Indicators of Stress in Simultaneous Interpreting*. PhD Dissertation. Poznań: Wydawnictwo Naukowe UAM.
- Kruger, Haidee. 2016. “What’s Happening When Nothing’s Happening? Combining Eyetracking and Keylogging to Explore Cognitive Processing during Pauses in Translation Production.” *Across Languages and Cultures* 17 (1): 25–52. <https://doi.org/10.1556/084.2016.17.1.2>
- Kurz, Ingrid. 2008. “The Impact of Non-Native English on Students’ Interpreting Performance.” In *Efforts and Models in Interpreting and Translation Research*, edited by Gyde Hansen, Andrew Chesterman, and Heidrun Gerzymisch-Arbogast, 179–192. Amsterdam: John Benjamins.
- Laufs, H., A. Kleinschmidt, A. Beyerle, E. Eger, A. Salek-Haddadi, C. Preibisch, and K. Krakow. 2003. “EEG-correlated fMRI of Human alpha Activity.” *Neuroimage* 19 (4): 1463–1476. doi:10.1016/S1053-8119(03)00286-6
- Lehtonen, Minna, Anna Soveri, Aini Laine, Janica Jarvenpää, Angela de Bruin, and Jan Antfolk. 2018. “Is Bilingualism Associated with Enhanced Executive Functioning in

- Adults? A Meta-Analytic Review.” *Psychological Bulletin* 144 (4): 394–425.  
doi:10.1037/bul0000142
- Lerner, Jennifer S., Ronald E. Dahl, Ahmad R. Hariri, and Shelley E. Taylor. 2007. “Facial Expressions of Emotion Reveal Neuroendocrine and Cardiovascular Stress Responses.” *Biological Psychiatry* 61 (2): 253–60.
- Mackintosh, Jennifer. 2002. The AIIC Workload Study - Executive Summary. Last accessed May 29th, 2019. < <https://aiic.net/page/888/the-aiic-workload-study-executive-summary/lang/1>>.
- McAllister, Robert. 2000. “Perceptual Foreign Accent and its Relevance for Simultaneous Interpreting.” In *Language Processing and Simultaneous Interpreting*, edited by K. Hyldenstam, and Birgitta Englund Dimitrova, 45–63. Amsterdam: John Benjamins.
- Muhl, Christian, Camille Jeunet, and Fabien Lotte. 2014. “EEG-based Workload Estimation across Affective Contexts.” *Frontiers in Neuroscience* 8 (114).  
doi:10.3389/fnins.2014.00114
- Muñoz, Edinson, Noelia Calvo, and Adolfo M. García. 2019. “Grounding Translation and Interpreting in the Brain: What has been, can be, and must be Done.” *Perspectives* 27 (4): 483–509. DOI: 10.1080/0907676X.2018.1549575
- Muñoz Martín, Ricardo. 2012. “Just a Matter of Scope. Mental Load in Translation Process Research.” *Translation Spaces* 1: 169–178.
- Oakes, Terrence R., Diego A. Pizzagalli, Andrew M. Hendrick, Katherine A. Horras, Christine L. Larson, Heather C. Abercrombie, Stacey M. Schaefer, John V Koger, and Richard J. Davidson. 2004. “Functional Coupling of Simultaneous Electrical and Metabolic Activity in the Human Brain.” *Human Brain Mapping* 21 (4): 257–270.  
doi:10.1002/hbm.20004
- O’Brien, Sharon. 2010. “Eye Tracking in Translation Process Research: Methodological Challenges and Solutions.” In *Methodology, Technology and Innovation in Translation Process Research: A Tribute to Arnt Lykke Jakobsen*, edited by Inge M. Mees, Fabio Alves, and Susanne Göpferich, 251–266. Frederiksberg: Samfundslitteratur.
- Paap, Kenneth R., Hunter A. Johnson, and Oliver Sawi. 2015. “Bilingual Advantages in Executive Functioning either do not Exist or are Restricted to Very Specific and Undetermined Circumstances.” *Cortex* 69: 265–278. doi:10.1016/j.cortex.2015.04.014
- Perani, Daniela, and Jubin Abutalebi. 2005. “The Neural Basis of First and Second Language Processing.” *Current Opinion in Neurobiology* 15 (2): 202–206.  
doi:10.1016/j.conb.2005.03.007
- Petsche, H., S. C. Etlinger, and O. Filz. 1993. “Brain Electrical Mechanisms of Bilingual Speech Management - an Initial Investigation.” *Electroencephalography and Clinical Neurophysiology* 86 (6): 385–394. doi:10.1016/0013-4694(93)90134-H
- Plevoets, Koen, and Bart Defrancq. 2016. “The Effect of Informational Load on Disfluencies in Interpreting.” *Translation and Interpreting Studies* 11 (2): 202–224.
- Price, Cathy J. 2012. “A Review and Synthesis of the First 20 Years of PET and fMRI Studies of Heard Speech, Spoken Language and Reading.” *Neuroimage* 62 (2): 816–847.  
doi:10.1016/j.neuroimage.2012.04.062
- Rinne, J. O., J. Tammola, M. Laine, B. J. Krause, D. Schmidt, V. Kaasinen, M. Teräs, H. Sipilä, and M. Sunnari. 2000. “The Translating Brain: Cerebral Activation Patterns during Simultaneous Interpreting.” *Neuroscience Letters* 294 (2): 85–88. doi:10.1016/S0304-3940(00)01540-8
- Rodriguez-Fornells, Antoni, Ruth De Diego Balaguer, and Thomas F. Munte. 2006. “Executive Control in Bilingual Language Processing.” *Language Learning* 56: 133–190.  
doi:10.1111/j.1467-9922.2006.00359.x

- Rodriguez-Fornells, Antoni, Michael Rotte, Hans-Jochen Heinze, Tömmе Nosselt, and Thomas F. Munte. 2002. "Brain Potential and Functional MRI Evidence for How to Handle Two Languages with One Brain." *Nature* 415 (6875): 1026–1029. doi:DOI 10.1038/4151026a
- Sabatini, Elisabetta. 2000. "Listening Comprehension, Shadowing and Simultaneous Interpreting of Two 'Non-standard' English Speeches." *Interpreting* 5 (1): 25–48.
- Seeber, Kilian G. 2011. "Cognitive Load in Simultaneous Interpreting. Existing Theories - New Models." *Interpreting* 13 (2): 176–204.
- Seeber, Kilian. 2013. "Cognitive Load in Simultaneous Interpreting. Measures and Methods." *Target* 25 (1): 18–32. doi 10.1075/target.25.1.03
- Seeber, Kilian. 2015. "Cognitive Load." In *Routledge Encyclopedia of Interpreting Studies*, edited by Franz Pöchhacker, 60–61. London: Routledge.
- Seeber, Kilian G., and Dirk Kerzel. 2012. "Cognitive Load in Simultaneous Interpreting: Model Meets Data." *International Journal of Bilingualism* 16 (2): 228–242.
- Sweller, John, Jeroen J. G. van Merriënboer, and Fred G. W. C. Paas. 1998. "Cognitive Architecture and Instructional Design." *Educational Psychology Review* 10: 251–295.
- Tommola, Jorma, and Pekka Niemi. 1986. "Mental Load in Simultaneous Interpreting: An Online Pilot Study." In *Nordic Research in Text Linguistics and Discourse Analysis*, edited by Lars S. Evensen, 171–184. Trondheim: Tapir.
- Van de Putte, Eowyn, Wouter De Baene, Lorna Garcia-Penton, Evy Woumans, Aster Dijkgraaf, and Wouter Duyck. 2018. "Anatomical and Functional Changes in the Brain after Simultaneous Interpreting Training: A Longitudinal Study." *Cortex* 99: 243–257. doi:10.1016/j.cortex.2017.11.024
- Van Dijk, Teun A., and Walter Kintsch. 1983. *Strategies of Discourse Comprehension*. New York: Academic Press.
- Wickens, Christopher D. 1984. "Processing Resources in Attention." In *Varieties of Attention*, edited by Raja Parasuraman, and D. R. Davies, 63–102. New York: Academic Press.



## **Biosketches**

**Michaela Albl-Mikasa** is Professor of Interpreting Studies in the ZHAW Institute of Translation and Interpreting. Her research and publications focus on ITSELF (interpreting, translation and English as a lingua franca), the cognitive foundations of conference and community interpreting, the development of interpreting expertise, and medical interpreting. She is principal investigator of the SNSF Sinergia project *Cognitive Load in Interpreting and Translation* (CLINT) and involved in smaller-scale projects with partners from China, India, and the ASEAN region.

**Maureen Ehrensberger-Dow** is Professor of Translation Studies in the ZHAW Institute of Translation and Interpreting. She was principal investigator of the interdisciplinary project *Cognitive and Physical Ergonomics of Translation (ErgoTrans)*, a follow-up of the *Capturing Translation Processes (CTP)* project, and is currently co-investigator of the CLINT project (all funded by the Swiss National Science Foundation).

**Caroline Lehr** is a research associate in the ZHAW Institute of Translation and Interpreting. She received her PhD from the University of Geneva in 2014. Her research focuses on the cognitive and affective aspects of translation and interpreting processes.

**Andrea Hunziker Heeb** is a research associate in the ZHAW Institute of Translation and Interpreting. She completed her PhD at the University of Hildesheim in 2019 and has been involved in translation process research since 2010, with a focus on cognitive load and directionality.

**Michael Boos** is a doctoral student in the Department of Neuropsychology in the laboratory of Prof. Lutz Jäncke at the University of Zurich. His work centers on speech and language processing, language expertise, and cognitive workload measurements.

**Matthias Kobi** is a doctoral student in the Department of Neuropsychology in the laboratory of Prof. Lutz Jäncke at the University of Zurich. His interests are speech and language processing, language expertise, and cognitive workload measurements.

**Lutz Jäncke** is Full Professor for Neuropsychology at the University of Zurich and a recognized expert in the field of cognitive neuroscience and plasticity research. Currently, he is the director of the University of Zurich Research Priority Program “Dynamics of Healthy Aging” as well as co-investigator of the SNSF-financed CLINT project. His main research interests are brain plasticity, learning and functional neuroanatomy with a special focus on how the human brain is shaped by experience.

**Stefan Elmer** is a senior researcher in the Department of Neuropsychology at the University of Zurich and head of the Auditory Research Group Zurich (ARGZ) within the laboratory of

Prof. Lutz Jäncke. In recent years, he has contributed fundamentally to a better understanding of the functional and anatomical correlates of simultaneous interpreting. Since 2010, he has been one of the most active scientists investigating the neural underpinning of simultaneous interpreting.