Cognitive load in relation to non-standard language input

Insights from interpreting, translation and neuropsychology

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The linguistic, psycholinguistic, and neural processes underlying simultaneous interpreting and translation have attracted widespread interest in the research community. However, an understanding of the cognitive load associated with these bilingual activities is just starting to emerge, and the underlying behavioral and physiological mechanisms are still poorly understood. In this article, we describe a promising interdisciplinary 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 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 English as Lingua Franca.

Keywords: simultaneous interpreting, English as a lingua franca, cognitive load, mixed methods, EEG

1. Introduction

Simultaneous interpreting (SI) is one of the most demanding bilingual language processing tasks (Christoffels & de Groot 2005, 454). As such, it has sparked interest outside the discipline of translation studies, such as in psycholinguistics,

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neuroscience, and neuropsychology, as researchers try 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. In 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. Translation studies has also 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 and translation scholars might be criticized for their use of less-than-objective measures with very small samples whereas neuroscientists and neuropsychologists confine their studies to laboratory settings with small linguistic units such as isolated words and phrases as stimuli, which do not take into account the real-life requirements and challenges of the interpreting task.

Societal developments and increased mobility introduce additional challenges to interpreters' activity that can complicate bilingual processing and potentially increase their cognitive load.[1] One of these is the global spread of *English as a lingua franca* (ELF), with the result that 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 2018) suggest that non-standard English input may place additional demands on interpreters' processing.

Against this background, our interdisciplinary team of interpreting, translation, and neuropsychology researchers decided to combine good practices from our respective disciplines in order to develop a new mixed-method approach for evaluating cognitive load during interpreting and translation.[2] The aims are mul-

1. Unless indicated otherwise, *interpreters* refers to professional simultaneous interpreters and *translators*, to professional translators.

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

tifold 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. Second, 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.

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 on cognitive load in interpreting studies to date and the reason for this dearth. We then present a brief overview of neuropsychological results regarding cognitive control and mental load in SI. This is followed by preliminary pieces of evidence that point to ELF adding to interpreters' cognitive load. 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. 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 before considering future directions.

2. Cognitive load in interpreting studies

Cognitive load is a multifaceted theoretical construct composed of many intertwined factors. In the classical definition, it encompasses load intrinsic to the task and extraneous load, which varies depending on the task presentation (see Sweller et al 1998; Chen et al 2012).

Increased load can be assumed to manifest itself in subjective feelings of stress, working memory burdens, behavioral changes, and physiological responses. 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.

However, 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 efforts model for SI, which treat it as the management of mental capacity, proceeds from the assumption that interpreters work close to saturation and that if cognitive processing requirements exceed the total capacity available, it may lead to interpreting problems. According to Gile (2008, 59), "[t]he effort model of SI is a cognitive framework. It conceptualizes SI as a set of multiple cognitive operations which can be grouped into three 'Efforts'" that draw on a single pool of resources. As 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 model, it is based on the notion of multiple resources and 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 texts in that this would suggest that the re-interpretation effort during comprehension of non-standard input might add to cognitive load.

In order to measure local cognitive load, Seeber suggests cognitive pupillometry (i.e., mean pupil dilation). The first such study of the effect of directionality-contingent syntactic complexity on mental load by Tommola & Niemi (1986) was followed by pupillometry studies that confirmed general interpreting wisdom, namely that SI is more demanding than repeating speech input (i.e., shadowing); shadowing is more load-intensive than listening comprehension (Hyönä et al 1995); 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 to quantify the 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 multilinguals need cognitive control for functions such as selecting which language to use (Rodríguez et al 2006; Abutalebi & Green 2007), avoiding negative transfer between different language systems, inhibiting the non-target language (Rodríguez et al 2002), and switching between languages (Garbin et al 2011; Price 2012). The brain regions supporting cognitive control in bilinguals have been described in detail (Rodríguez et al 2006; Abutalebi & Green 2007), and numerous studies (see below) 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, adapted from Abutalebi & Green 2007). Nevertheless, the exact influence of bilingualism and multilingual experience on cognitive and executive functions remains unclear (Paap et al 2015; Lehtonen et al 2018). The neuroimaging studies in the next section provide some insight into the possible relationship in the context of SI.

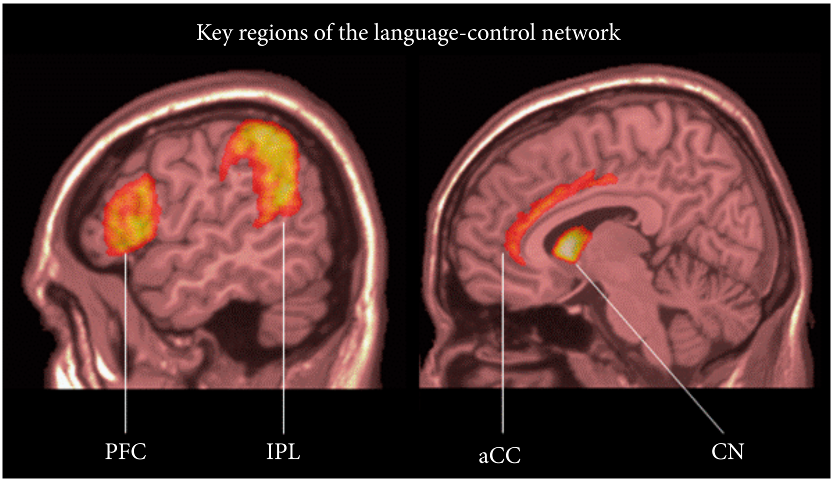

Figure 1. Schematic illustration (lateral view) of brain regions identified as essential for cognitive control in multilinguals. PFC = prefrontal cortex; IPL = inferior parietal lobule; aCC = anterior cingulate cortex; CN = caudate nuclei

3.1 Functional neuroimaging studies

SI is generally accepted to be cognitively more demanding than other types of language control activities, which has prompted an interest in elucidating its functional underpinnings. In one of the first neuroimaging studies, Rinne et al (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 second 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 shadowed simple sentences with a subject-verb-object (SVO) structure. Analyses based on *a priori*-defined brain regions 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 linguistic 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 (Elmer et al 2011a; Becker et al 2016; 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 respective 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 (Elmer et al 2011b, 2014, 2019; Becker et al 2016; 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 et al (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 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 fewer mixing costs in a task-switching experiment, 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 grey matter plasticity may follow 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. 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 pioneering 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 on this relatively under-researched area.

3.3 Electrophysiological studies

Several electrophysiological (EEG) studies have tried to (indirectly) measure indices of cognitive load during intra- and interlingual language processing tasks such as SI. Petsche et al (1993) conducted the first study of this type and measured brain activity in three interpreters while they silently interpreted sentences L1→L2 or L2→L1 (see also Kurz 1993). 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, which is a more demanding task than translation into the native language.

In a recent EEG study, Dottori et al (2020) examined the behavioral and electrophysiological correlates of overt word reading and translation in a sample of professional simultaneous interpreters and non-interpreter bilinguals. During the reading and translation tasks, the participants were instructed to read or translate aloud single words as fast and accurately as possible and to press a response key at the beginning of articulation. Results showed that simultaneous interpreters exhibited increased EEG power in the delta-theta frequency range across all linguistic tasks compared to the non-interpreter bilinguals. However, the authors only detected behavioral group differences in the translation condition, with faster performance in simultaneous interpreters. Furthermore, electrophysiological between-group differences were most pronounced in the L2→L1 translation task, which usually corresponds to the most commonly practiced interpreting direction. Notably, in the L2→L1 translation task the authors also noticed a negative correlation in the interpreters' group between reaction time and delta-theta power in frontal and right posterior electrode clusters. Taken together, these results support the notion that professional interpreting training leads to a general reconfiguration of the neural substrate involved in language processing (Elmer et al 2019), and that the L2→L1 direction is associated with the most prominent functional changes and a close brain-behavior relationship. 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 researchers 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. 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 experimental 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 L1, 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 interpreters' critical attitudes 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).

One of the first surveys on ELF in relation to interpreting revealed the adverse effects of non-standard input by L2 English speakers on interpreters' capacity management (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, reformulation, 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 language 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' mental workload and is vital for fundamental SI processes such as inferencing and anticipation. Destabilization of automatized processes was found in a small-scale study involving three ELF speakers and an interpreting student and reflected in the retrospective interviews with both the ELF speakers and the interpreting student (Albl-Mikasa 2013a). The findings suggested that retrieval of established transfer routines and translation equivalent links was impeded. This phenomenon could be at the root of interpreters' complaints that ELF acts as a "brain stopper" (Albl-Mikasa 2014, 23).

Other small-scale studies have identified various ELF-related factors that may increase cognitive load. For example, foreign accents have been investigated by a number of researchers (e.g., McAllister 2000; Sabatini 2000; Cheung 2003; Kurz 2008). One of the present article's co-authors has focused on other linguistic aspects such as unconventional and incomplete structures, unusual lexical expressions or logical irregularities (Albl-Mikasa 2010, 2013a) as well as text organization and restricted application of text development and audience design conventions

(Albl-Mikasa et al 2017a). In addition, the lack of a "shared languages benefit"—i.e., interpreters not having the ELF speaker's L1 in their working languages repertoire—has been identified as relevant adverse factors for processing ELF (Kurz & Basel 2009; Albl-Mikasa 2013b).

The above-mentioned studies have consolidated the assumption that it is not necessarily each of the listed factors by itself that might induce additional 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 relevant 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 or edited texts, three of each were translated by six European, but non-EU, 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 associated with non-standard input

Since cognitive load is a complex construct, the most convincing way to capture its various dimensions is to use a mixed method approach that includes a variety of measures to assess the potential cognitive load of non-standard input. Chen et al (2012) have divided these measures into different categories: subjective, physiological, behavioral, and performance measures. In our current research, we are assessing the potential cognitive load of non-standard input in a comprehensive way with measures covering all the categories, combined in a complementary fashion to elucidate the phenomenon from different angles with the same participants in two different settings, namely a simulated workplace and a neuropsychology laboratory setting, as explained below.

Virtually all available measures of cognitive load are only indirect indicators. In educational psychology, where cognitive load theory originated (Sweller et al 1998), as well as 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.

5.1 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 of computer workplaces with access to online resources for translation. 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 an ELF and an EdE text, whereas interpreters and MA interpreting students perform SI of ELF and EdE speeches (middle of Figure 2).[3] 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).

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 and perceived workload immediately after each task (i.e., STAI and NASA Task Load Index, respectively). As complements to self-report assessments, physiological correlates of cognitive load provide indications 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 as to its validity—pupil size is known to be sensitive to many factors apart from cognitive activity (O'Brien 2010, 253)—it might provide information about processing

3. For more details about how the texts were prepared, see Ehrensberger-Dow et al 2020.

ELF. Heart rate is another physiological measure being taken, since it has been identified as an indicator of stress during SI (Korpal 2017; Mackintosh 2002).

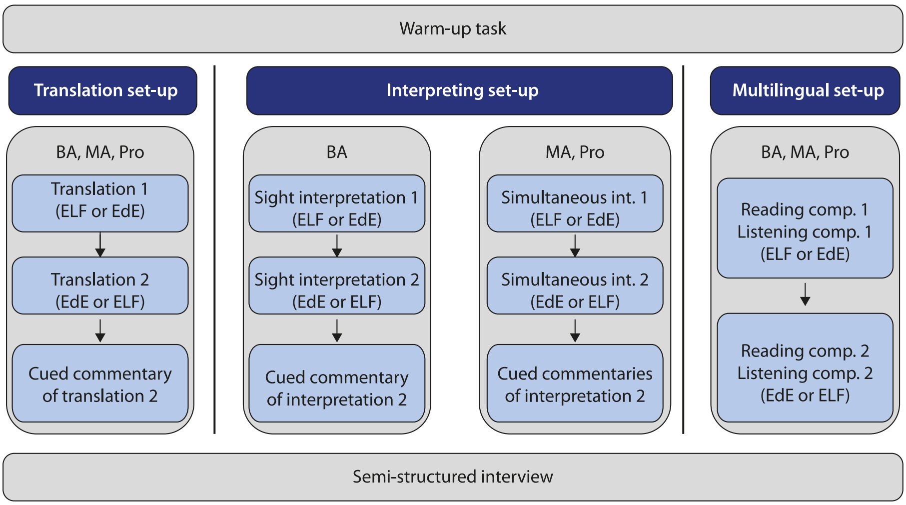

Figure 2. Design for the simulated workplace setting

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 (e.g., Hvelplund 2017; Vieira 2017; Herbig et al 2019). In our project, these various sources of data 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. Various eye-tracking measures are used in both the translation and the interpreting tasks. Other behaviors that may be indicators of cognitive load in both types of tasks are gesturing (cf. Goldin-Meadow et al 2001) and facial expressions (cf. Herbig et al 2019).

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 (e.g., 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 (e.g., Kruger 2016). The overall quality of the target texts, which can be assessed through subjective evaluations by expert raters or potential users may also be indicative of the cognitive load generated by processing ELF.

5.2 Neuropsychology laboratory setting

The main motivation for also carrying out tests in the controlled setting of the neuropsychology laboratory 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- or written 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.

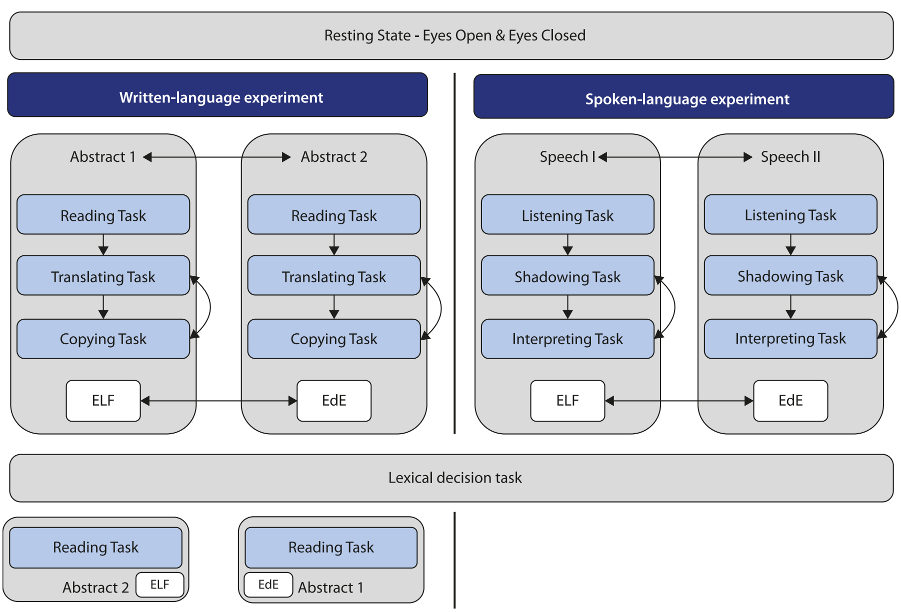

Figure 3. Experimental settings for the written-language and spoken-language tasks

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 (silent) shadowing will be alternated with short periods of overt (aloud) shadowing 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 copy type or translate as much source text as possible within a fixed time window of five minutes. The presentation of the stimuli in the translating and copying tasks is sentence-by-sentence, an adaptation of the work environment 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 the translating task, the process of L2→L1 translation is added to the participants' cognitive workload. After a lexical decision task (i.e., word vs. pseudoword) which was unrelated to the main project and targeted at evaluating intra- and interlingual language processing as a function of language 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 and EdE.

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, Calvo & García 2019; see also Zhao & Dong, this issue). 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 their professional lives. Since ELF can deviate 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 language 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 tasks 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 the reduced ecological validity, which seriously limits any generalizations to T&I practice. The new approach taken here in using larger text units than simply words or phrases 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 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 neuropsychology, interpreting studies, and translation studies, respectively, and has developed and benefited from reciprocal input. This article is intended to serve as both a theoretical and a methodological 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 as well as in the area of ELF.

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