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Capacity, load and effort in translation, interpreting and bilingualism.

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1. Introduction

The ability to communicate through language, which is often said to set humans apart from other animals, is governed by complex cognitive processes enabled by a similarly complex cognitive architecture. Yet the human brain is able to comprehend and produce both written and spoken language – in fact, more often than not, several languages (Grosjean, 2010). Along with those who use their language(s) socially, there are those who use them professionally, including authors, editors, interpreters, proofreaders, revisors, stenographers and translators. Effortless though it might seem (Harley, 2014; Carroll, 2008), the process of speaking, listening, reading and writing even just one - let alone multiple – language(s) is not inconsequential for the human brain, and is limited by what the brain can accomplish at any given time. This is where the notions of capacity, load and effort come into play. Rather than focusing on the methods or metrics used to quantify these constructs as they relate to multilingual language processing (see Tirkkonen-Condit & Jääskeläinen, 2000; Seeber, 2013; Chen, Zhou, Wang, Yu, Arshad, Khawaji, & Conway, 2016; de Groot & Hagoort, 2018 for a review), this chapter attempts to provide an overview of how the constructs of capacity, load and effort have informed our understanding of different language-related processes and tasks, in particular those more directly related to the tasks and activities performed in multilingual professions. To that end, we will briefly introduce these theoretical constructs, all of which have evolved outside the field of bilingualism or translation and interpreting studies, and then relate them to the tasks most often performed by ordinary and professional bilinguals.

2. Concepts and definitions

The estimated storage capacity of the human brain has recently been revised upwards and put in the range of several million gigabytes (Bartol, Bromer, Kinney, Chirillo, Bourne, Harris, & Sejnowski, 2015). This refers to the staggering amount of information the average human can keep in long-term memory. When it comes to working memory, however, which refers to the part of the human processor used for temporary storage and manipulation of information (Baddeley, 1996), its severely limited capacity is well documented (Cowan, 2001, 2010; Klingberg, 2009; Marois & Ivanoff, 2005). This is why, over the years, constructs like resources, capacity, load and effort have been used to describe and explain the limitations of cognitive processes (Chen et al., 2016), including those related to language.

2.1 Capacity

The construct of *capacity* is usually related to that of working memory and generally understood as the maximum number of resources the system can deploy in order to temporarily retain and process information at a given time. When these resources are inadequately allocated to a task, or when the task exceeds the maximum number of resources available, task performance will suffer or fail altogether (Paas, Tuovinen, Tabbers, & VanGerven, 2003). More or less complex memory span tasks have been designed to quantify working memory capacity across different processing modalities and codes, including listening to as well as reading words and numbers. These tasks can accurately measure the number of successfully processed and retrieved discrete items, thus providing a reliable working memory capacity metric (Barrouillet & Camos, 2007). The early idea of a unitary resource fueling all cognitive activity (Kahneman, 1973), however, seems to have given way to a more faceted construct of multiple different resources (Wickens, 1984) available for tasks characterized by specific processing stages (perception, cognition and responses), codes (manual-spatial or vocal-verbal) and modalities (auditory or visual). Consequently, specific resources will be depleted more quickly when different tasks relying on the same stages, codes and modalities are executed at the same tame.

2.2. Load

If *capacity* attempts to capture the number of resources available for the execution of a cognitive task, then cognitive *load* tries to quantify the processing demands particular tasks place on these mental resources (Chen et al., 2016). This notion has been captured from an endogenous perspective, e.g., by Curry, Jex, Levison, & Stassen (1979), who describe load in terms of the effort devoted to control and/or supervision relative to the capacity to expend it, or O'Donnell and Eggemeier (1986), who conceive of it as the part of capacity actually required to perform a task. Conversely, and more frequently, it has been framed from an exogeneous perspective, e.g., by Paas and Merriënboer (1994), who see it as the demands the performance of a particular task impose on the cognitive system, or by Wickens (2008), who explains it as equivalent to the number of cognitive resources elicited during the execution of a task. The notion of load finds its origins in educational psychology, more specifically in the construct of Cognitive Load Theory (CLT). It was developed by Sweller (see Sweller et al., 2011) to conceptualize and differentiate the processing demands imposed by the nature of learning materials (i.e., intrinsic load), the demands associated with the way in which these learning materials are presented (i.e., extraneous load) and the demands actually associated with the learning of the materials (i.e., germane load). In cognitive psychology, load is generally accepted as being a dynamic measure of the resource demands imposed by one or several tasks.

2.3. Effort

The construct of *effort* was formally introduced by Moray (1967) and is defined by Paas et al. as, "the aspect of cognitive load that refers to the cognitive capacity that is actually allocated to accommodate the demands imposed by the task" (2003:64). It seems to be closely related to attention, difficulty, motivation, or fatigue. And yet, attention can be experienced as effortful or effortless, depending on whether it occurs under sympathetic dominance (Bruya & Tang, 2018). When tasks primarily engage the sympathetic nervous system (SNS), energy is mobilized triggering physiological changes such as the increase of cardiac output and pupil size as well as the acceleration of respiration rate. Conversely, when tasks mainly engage the parasympathetic nervous system (PSNS), no such physiological changes are experienced. Similarly, a task can be perceived as being difficult not because of resource limitations, but because of data limitations (Norman & Bobrow, 1975). Motivation, finally, can affect performance by modulating effort (Massar et al., 2020), just like fatigue seems to affect motivation and regulate how much effort is deployed (Hopstaken, van der Linden, Bakker, & Kompier, 2015). This means that, while effort seems to capture the degree of engagement with demanding tasks, the construct Paas and Merriënboer (1994) consider essential for a reliable estimate of cognitive load remains largely underexplored. We do know, however, that decision-makers try to minimize effort (Kool, McGuire, Rosen, & Botvinick, 2010) and that increases in effort can keep performance stable (within limits) in spite of increasing load, although once overload is reached, compensatory efforts no longer affect performance (Chen et al., 2016).

3. Monolingual tasks

3.1 Comprehension

Oral language comprehension takes place very rapidly (Marslen-Wilson, 1973; Rayner & Clifton, 2009) and appears to be completely effortless (Harley, 2014). Listeners convert acoustic input into meaning by decoding phonemes and parsing them into recognizable words, processing their syntax, assigning thematic roles, and extracting the meaning of utterances by integrating pragmatic, discourse and knowledge-based factors (Cutler & Clifton, 2000).

However, the comprehension process does not stop at the level of word recognition. Listeners go on to integrate the information contained in words into a linguistic and extra-linguistic context which, in turn, influences the comprehension of upcoming words both when people listen (Huette, Winter, Matlock, Ardell, & Spivey, 2014; Tanenhaus, Spivey-Knowlton, Eberhard, & Sedivy, 1995) and when they read (Altarriba, Kroll, Sholl, & Rayner, 1996; Ehrlich & Rayner, 1981). Finally, the comprehension process goes beyond the integration of words into a preceding context: there is evidence that comprehenders predict the meaning, syntax and phonology of upcoming content both when reading and when listening (see Pickering & Gambi, 2018 for a review).

In general, the speed of listening comprehension is determined by the comfortable natural speech rate, which seems to range between 150 wpm and 160 wpm (Rayner et al., 2016), although audiobooks are recorded at rates of between 140 wpm and 180 wpm (Brysbaert, 2019), and, in natural conversation, speakers reach speech rates of 200 wpm (Laver, 1994)[1]. Reading comprehension is faster. A recent meta-analysis revealed that the typical silent reading rate is between 240 wpm and 260 wpm (Brysbaert, 2019). In addition, various techniques can increase reading speed, although generally at the expense of comprehension (Rayner, Schotter, Masson, Potter, & Treiman, 2016). Unlike listening comprehension, reading comprehension may not always be strictly sequential, meaning that readers tend to go back and read over parts of the text again (Brysbaert, 2019).

Additional capacity-related processing difficulties may be encountered at any stage in reading and listening comprehension: word recognition, syntactic processing, thematic role assignment and extraction of meaning. Word recognition is worse for low frequency words compared to high frequency words (e.g., Guttentag & Carroll, 1997), and, in noisy

[1] While speech rates vary across languages (see Pellegrino et al. 2011, Rodero 2012) they mostly fall within these approximate ranges.

conditions, low frequency words are incorrectly perceived more often than high frequency words (Savin, 1963). More recently, increases in cognitive load as a function of word frequency have been measured neurophysiologically (Berglund-Barraza, Tian, Basak, & Evans, 2019). Meanwhile, reading speed is slowed when readers encounter garden-path sentences, such as “The horse raced past the barn fell”: readers tend to assume that “horse” is the agent of “race”, and this is disconfirmed by the final verb “fell”, forcing a readers to reanalyse the sentence (Clifton, 2001). Reading difficulty also increases for object-relative clauses compared to subject-relative clauses (e.g., “The lawyer that the banker irritated filed a hefty lawsuit” compared to “The lawyer that irritated the banker filed a hefty lawsuit”), as readers tend to assume that the initial subject encountered is also the subject of the relative clause. If this is not the case, readers reanalyse the sentence, and this reanalysis may be facilitated (or hampered) by semantic factors (Traxler, Morris, & Seely, 2002). Finally, sentence context influences word recognition during reading and listening (see Kutas & Federmeier, 2011).

Importantly, individual differences in working memory capacity influence how some of these factors affect language processing. For instance, higher working memory capacity increases the ease with which readers resolve inconsistencies in sentences (Daneman & Carpenter, 1983), the performance of listeners listening to non-native accented speech (McLaughlin, Baese-Berk, Bent, Borrie, & Van Engen, 2018) and predictive processing during listening (Huettig & Janse, 2016), but does not appear to affect the processing of garden-path sentences (Waters & Caplan, 1996).

3.2 Production

Generally, comprehension and production processes have been considered separately. However, these processes often go hand in hand, even in simple monolingual tasks such as everyday conversation.

While comprehension processes are traditionally viewed from the bottom up, production processes are often considered from the top down. The assumption, therefore, is that when speaking, people begin by conceptualizing their utterance, and then convert that concept into syntactic representations, before constructing the sound-based representations they articulate (Bock & Levelt, 1994). The conceptual level has traditionally been viewed as non-language specific, and non-automatic (Levelt, 1989). Once speakers decide on the message they wish to convey, they formulate the message by selecting words (lemmas) in their syntactic context, and activate their phonology (sound processing) before articulating.

In its later stages, the production process is traditionally considered to be automatic (Levelt, 1989) and thus to generate less load on the system. However, automaticity at all stages of production may be graded (Garrod & Pickering, 2007). Speakers and writers tend to produce higher frequency lexical items at lower latencies than lower frequency items (Bonin & Fayol, 2002), suggesting that the more frequent a word, the less effort is required to produce it (see also Caramazza, Costa, Miozzo, & Bi, 2001). Ferreira and Pashler (2002) provide evidence that lemma selection and word-form selection require cognitive resources, and are thus affected by performance of a concurrent task, while phoneme selection is not. There is also converging evidence suggesting that speech planning is more cognitively demanding than articulating (Boiteau, Malone, Peters, & Almor, 2014; Sjerps & Meyer, 2015). Speech monitoring may take place both before and after articulation (Hartsuiker, 2014; Hickok, 2014), and although errors detected before articulation may avoid the need for some overt repairs during production, they may still lead to disfluencies (Hartsuiker, 2014) and delays in speech planning (Boland, Hartsuiker, Pickering, & Postma, 2005), possibly indicating increased load.

Meanwhile, writers (and typists) generate word meanings and access words, and retrieve the phonology of these words and their corresponding orthographic representations (for familiar words, orthographic access may be direct, see Rapp & Caramazza, 1997), before typing or writing the words (Purcell, Turkeltaub, Eden, & Rapp, 2011). This written production, conditioned by additional load, may take longer than oral production (Perret & Laganaro, 2013).

3.3 Shadowing

Shadowing, in other words the overt verbatim repetition of an auditory message usually heard over headphones (Cherry, 1953), is among the simplest tasks which combine language comprehension and production processes in real time. Thus, it was not only used as a fundamental paradigm for the exploration of memory and attention in early psycholinguistic studies, but was also readily co-opted as a control task for studies into simultaneous interpreting (Hervais-Adelman, Moser-Mercer, Golestani, 2015; Green et al., 1990; Tommola et al., 2000; Treisman, 1964). A general distinction can be drawn between phonemic shadowing, which implies the repetition of sounds as soon as they become available, and phrase shadowing, entailing instead the repetition of meaningful phrases once they have been understood (Norman, 1976). Shadowing is cognitively complex because attentional resources need to be shared between two concurrent tasks, comprehension and production, and because of the task load on the phonological loop, i.e., the articulatory storage and rehearsal system (Baddeley, 2017) which attends to linguistic input and output.

Importantly, evidence of syntactic and semantic self-correction patterns both in close shadowers (i.e., those repeating input at a latency of 250-300ms) and distant shadowers (i.e., those repeating input at a latency of about 500ms) suggests that, contrary to what was previously assumed (see Gerver, 1974), higher-level information is accessed during both types of shadowing (Marslen-Wilson, 1985). This might, however, apply to shadowing in L1 more than it does to shadowing in L2, owing to resource limitations (Kadota, 2007). Consequently, shadowing is likely to comprise word recognition and integration as well as (at least some of the) predictive processing observed in ordinary comprehension. The extent to which certain parts of the production process are actually facilitated by concurrent comprehension remains unclear.

3.4 Paraphrasing

Paraphrasing can be defined as, "the restating of a sentence such that both sentences would generally be recognized as lexically and syntactically different while remaining semantically equal" (McCarthy, Guess, & McNamara, 2009: 682). In order to achieve semantic completeness whilst ensuring both lexical and syntactic difference, therefore, paraphrasing is assumed to require deductive and analogical inferential thinking (Yamada, 2003). This may be why some consider that paraphrasing is a form of intralingual translation, in other words, the production of a version of the original text in the same language for a different purpose or audience, with the sole distinguishing feature (as compared to interlingual translation) that the language barrier is not crossed (Whyatt, Stachowiak, & Kayzer-Wietrzny, 2016).

Besides having been used as a method to test comprehenders' interpretations of ambiguous or misleading sentences (Patson, Darowski, Moon, & Ferreira, 2009), paraphrasing has been suggested as a means to test aptitude for interpreters (Moser-Mercer, 1985) and as an exercise both for beginner and advanced interpreters (Setton & Dawrant, 2016). These applications are principally based on the argument that choosing synonyms in the same language, as is the case in paraphrasing, is comparable to selecting linguistic equivalents between languages, as is the case in translation or interpreting (Gran, 1992). Indeed, earlier research seemed to suggest similar processing load for both interpreting and paraphrasing based on similar ear-voice spans (Anderson, 1994), although more recent studies revealed longer latencies for paraphrasing than for interpreting (Christoffels & de Groot, 2004), which cautions against viewing paraphrasing as a monolingual version of interpreting. When high-frequency words need to be substituted by low-frequency words (albeit within the same language), for example, processing load might well exceed that of substituting a high-frequency word in one language by a high-frequency word in another. Similarly, syntactic adjustments within a language might inevitably lead to more complexity and thus engender more load than the mapping onto a comparable or simpler structure in another language.

3.5 Respeaking

This "method of producing subtitles to live programmes in real time using speech recognition technology" (Chmiel et al., 2018: 725), is usually carried out intralingually, although more recently also interlingually (Romero-Fresco & Pöchhacker, 2017), and has been viewed as belonging to the same multimodal continuum as shadowing and interpreting (Eugeni & Bernabé, 2021) given the real-time combination of different tasks requiring processing of information in different modalities. As a task, respeaking can be said to straddle the processes of shadowing and paraphrasing. Respeakers shadow the original, condense it by eliminating redundancies and selecting more concise formulations (predicated by the space-constraints for the subtitles generated), yet also verbalize punctuation marks (Eugeni, 2008).

An analytical case could therefore be made for the additional cognitive resource demands as compared to shadowing and paraphrasing.

Evidence suggests that, while experience in translation or interpreting does not seem to improve respeaking performance, it does appear to affect the respeaking process: interpreters are better at eliminating semantic redundancy than translators who, in turn, outperform bilinguals; they are also less affected by the simultaneity of the task (Chmiel et al., 2018). Therefore, while Eugeni and Bernabé (2021) make a strong analytical case for the cognitive similarities between respeaking and interpreting, the available empirical evidence currently does not bear this out, suggesting that the so-called interpreter advantage might not be directly transferrable to paraphrasing as performed in respeaking (Chmiel et al., 2018).

4. Multilingual tasks

4.1 Multilingual comprehension

Models of comprehension in bilinguals and multilinguals account in different ways for the parallel activation of multiple languages. The BIMOLA model for bi- and multilingual word recognition (Grosjean, 1988, 1997), for example, is inspired by the TRACE model. It assumes that different languages are stored in separate lexicons, but that both languages share the lowest feature level and begin to separate into different networks at the phoneme and word level (Grosjean, 1988). In contrast, in their BIA+ model, Dijkstra and van Heuven (2002) propose that language activation is non-selective at the orthographic, phonological and semantic levels. This model accounts for top-down effects (lexical, syntactic or semantic) on word identification, as well as on the extent of activation of each language. Both languages are assumed to be active, to some extent, all the time, as it does not seem possible to suppress one reading of an interlingual homograph while activating another (Dijkstra & van Heuven, 2002). Dijkstra, Wahl, Buytenhuijs, Van Halem, Al-Jibouri, De Korte and Rekké (2019) propose and implement a computation model which combines elements of the BIA+ model with the Revised Hierarchical Model (Kroll & Stewart, 1994; reviewed in Section 4.2), which also assumes concurrent activation of both languages but which includes factors which modulate this activation. However, there is still some debate in the literature about the exact extent to which, and point in time when, both languages are activated (Costa, Pannunzi, Deco, & Pickering, 2019; Thierry & Wu, 2007).

The effect of multilingualism on comprehension is well documented. For instance, reading speed in L2 speakers is between 10% (Dirix, Brysbaert, & Duyck, 2019) and 17% slower (Cop, Drieghe, & Duyck, 2015) than in L1 speakers.

Listening comprehension is often difficult for L2 learners, but individual differences in general language proficiency and vocabulary knowledge explain much of the variance in listening comprehension (Wang & Treffers-Daller, 2017). Using pupil size as a measure, Schmidtke (2014) found increased cognitive effort during word activation L2 listeners than in L1 listeners, which they attribute to L2 listeners' reduced language experience in their L2. Meanwhile, Satori (2021) found that while working memory capacity was linked to measures of L2 listening comprehension in lower proficiency L2 speakers, there was no clear link between working memory and L2 listening comprehension in high proficiency speakers.

Of course, in general, there is significant diversity among the bilingual population with regard to factors including language history, linguistic environment and level of proficiency (Grosjean, 1998) and this may affect the effort that listeners need to make during comprehension.

4.2. Multilingual production

There is extensive evidence of cross-linguistic activation at almost every level of representation, and this is also the case for language production (for a review see Brysbaert

& Duyck, 2010). While earlier models of bilingual production supposed that L1 and L2 were stored in two separate lexicons (De Bot, 1992; Kroll & Stewart, 1994), more recent models converge on their assumption of cross-linguistic activation. However, unlike in speech recognition, where a bilingual's other language may be activated in a bottom-up manner (Dijkstra & van Heuven, 2002), speakers do exert some control over which language is activated for word production (Costa & Santesteban, 2004). This control is the focus of Green and Abutalebi's (2013) adaptive control model for bilingual production, which assumes that bilinguals must suppress lexical competition from their other language(s) to achieve communication in one of their languages only. This contrasts with monolingual models of speech production, which do not assume this kind of inhibitory process (Costa, 2005). Importantly, Green and Abutalebi (2013) assume that bilingual production involves more cognitive control than monolingual production; that regularly exercising cognitive control for language selection leads to enhanced cognitive control in bilinguals; and that this enhanced cognitive control also manifests in nonverbal tasks.

However, the price of interference from other language(s) during language processing in bilinguals may be that language production is more effortful (Bialystok, Craik, Green, & Gollan, 2009). For instance, bilinguals are slower than monolinguals at picture naming (Gollan, Montoya, Fennema-Notestine, & Morris, 2005; Ivanova & Costa, 2008). Of course, this may also be due to frequency effects, because bilingual speakers will use both lexicons proportionally less than monolingual speakers, making each lexical entry less frequent. Furthermore, the typical age-of-acquisition of a particular word may also affect lexical retrieval, potentially confounding frequency effects. An interference account is therefore not the only way to explain these findings.

4.3. Code mixing and code switching

Although there is some debate about whether bilinguals activate both of their languages all the time (see Costa, Pannunzi, Deco, & Pickering, 2017), both languages are activated when they are both in use. This applies to intentional and unintentional code mixing, often defined as mixing language(s) within a single sentence, and code switching, defined as switching language(s) between sentences (Kutas, Moreno, & Wicha, 2009). While intentional code switching may rely on inhibition of the other language(s), unintentional code switching may be due to an incorrect selection process (Kutas et al., 2009).

Code switching may require cognitive resources, but this is not always the case (Gullifer, Kroll, & Dussias, 2013), particularly when the speaker decides at what time to code-switch (Gollan & Ferreira, 2009). Code switching may also help listeners process unexpected information by signalling that the speaker is about to produce a lower-frequency word (Tomić & Valdés Kroff, 2021). The direction of language switching may also lead to greater or fewer switching costs. For instance, Kroll and Stewart's (1994) model assumes that L1 words are more strongly linked to the conceptual level than L2 words, suggesting that switching into L2 is more cognitively demanding in terms of lexical selection than switching into L1, although this is challenged by current evidence for cross-linguistic activation at almost every level of representation (for a review see Brysbaert & Duyck, 2010).

Of course, in translation and interpreting tasks, code switching is externally cued (Dong & Li, 2020), and this may require more cognitive effort than code switching at a time chosen by the speaker.

4.4. Written translation

Translation, a task requiring the processing of written input in one language and formulating written output in another, has been described as a "composite systemic activity" (Shreve, 2021:81) comprising different constituent processes fueled by cognitive resources.

These processes include the processing of input in the source language, the formulation of output in the target language, and the retrieval and evaluation of information (Ehrensberger-Dow, 2021). The oversimplified notion of written translation as a linear, sequential process, alternating between the reading of the original and the writing of the translation (Gile, 1995, 2009) does not reflect the reality of the task (Gile & Lei, 2021). Today, we have evidence not only of a considerable amount of attention switching between tasks and tools (Teixeira, 2014; Teixeira & O'Brien, 2017) but also that processes such as reading and writing regularly overlap, especially in experienced professionals (Hvelplund 2011, 2021, Balling, Hvelplund & Sjørup 2014; Schaeffer & Carl, 2013). This might, in turn, be conditioned by the fact that the temporal constraints under which modern professional translators have to perform can no longer be considered "virtually nonexistent" (Gile, 1995: 186) and are, in fact, substantial (Ehrensberger-Dow, 2021; Hyönä, Tommola, & Alaja, 1995; Muñoz Martín 2012, 2014).

As a complex task combining written text comprehension with written text production, translation, much like its component tasks, is bound to be conditioned by cognitive capacity, load and effort. These constructs have indeed been used widely to describe and explain a number of subtasks in the translation process, to the point that some consider it, "an implicit, partial theory of translation" (Muñoz Martín, 2012:170). Having said that, the load and effort resulting from the combination of these tasks into one, arguably more complex task, need not necessarily correspond to the sum of its parts. For instance, reading for the purpose of translating has been suggested to be more effortful than reading for comprehension (Lykke Jakobsen & Jensen, 2008; Shreve, Schäffner, Danks, & Griffin, 1993). Other types of load and effort are specifically related to transformation, such as the translation of metaphors, which seems to be associated with higher effort (Alves, Pagano, & da Silva, 2014; Tirkkonen-Condit 2002). It would appear that, in general, load increases with the number of translation options entertained simultaneously as they require effort to maintain (Teich, Martinez, & Karakanta, 2021). Similarly, Pym (2008) suggests maintaining only few translation hypotheses so working memory can be allocated more efficiently.

Beyond the translation task itself, Ehrensberger-Dow (2021) identifies poor ergonomic conditions as a potential source of cognitive load, with translators adjusting their cognitive processes to fit the ergonomic parameters of their workplace or indeed the machine interface, forcing them to deploy increased compensatory effort. Similarly, cognitive resources are said to be spent on ignoring distractions and thus go missing elsewhere in the process. Finally, Hansen-Schirra (2012) argues that the technical tools aimed at aiding translators at times add cognitive load owing to their complexity.

What emerges, therefore, is a picture somewhat at odds with Gile and Lei's suggestion that, "in translation, the intensity of expended cognitive effort is relatively low most of the time" (2021:267).

4.5. Post editing

The revisions that translators make during and after the translation process are generally seen as a constituent component of the human translation task (Carl et al. 2011). By contrast, the growing practice of revising a machine-generated translation, also known as post-editing, is recognized to be different enough from human revision to be considered in its own right (Sun 2019). In fact, the post editor’s principal objectives are to detect errors in the machine translation, which tend to be more recurrent and predictable than in a human translation (Vasconcellos, 1987), and to plan and perform the edits necessary (Koponen et al. 2012) to make the translation "acceptable for its intended purpose" (Koby 2001:1). The estimated cognitive effort associated with the post editing process has been used as a means to evaluate machine translation quality (Snover et al. 2006). However, the post editing process is complex, with substitutions, insertions and deletions of certain text constituents potentially affecting the remaining text, and thus necessitating further adjustments. What is more, the scope of the changes that post editors make to a machine translation, as well as the extent to which they use existing text constituents (rather than retyping text), vary substantially across translators and interact with each other (Koponen et al. 2012) making the task inherently multidimensional and the quantification of effort less than straightforward.

4.5. Sight translation

Sight translation involves reading a text and rendering it as an oral translation (Chmiel & Mazur, 2013). It thus involves code switching in a predetermined direction from source to target language, and at the same time the transfer of form from written to oral (Čeňková, 2010) (although the translator may view the text before beginning sight translation, see Kokanova, Lyutyanskaya, & Cherkasova, 2018). Sight translation is distinct from simultaneous interpreting with text because it involves a written input only (Setton, 2015). Importantly, therefore, the pace of translation, although expected to be fluent and steady, is not externally determined (Čeňková, 2015). However, the oral output is expected to be significantly faster than written translation (Dragsted & Hansen, 2009). Sight translation is thus sometimes used as a pedagogical tool in the teaching of simultaneous interpreting (Ho, 2017). The resources required for sight translation may vary depending on the text to be translated and the direction in which the translation is carried out.

Translators may be able to read some texts more quickly than others: for instance, when reading, translator look at predictable words for less time than words that are not predictable, and more frequently skip over high predictable words (Clifton, Staub, & Rayner, 2007), meaning that a text with many predictable words might be read faster. This could allow more resources to be devoted to production. Similarly, cognitive load may be reduced when translators already know precise information contained in the text, or when they are given information about the context of the text before being asked to start their translation (Kokanova et al., 2018). Conversely, longer and/or more complex sentences (such as garden-path sentences) might slow down comprehension and force reanalysis (Clifton, 2001): if the translator has already begun production, this could also conceivably lead to disfluencies or corrections (e.g., Hartsuiker, 2014).

By measuring fixation duration on sentences during a sight translation task, Chmiel and Mazur (2013) found that shorter sentences, containing words with fewer syllables, generated less cognitive load than longer sentences containing words with higher syllables. Meanwhile, Shreve, Lacruz and Angelone (2010) found that participants spent longer looking at areas of interest situated at complex than at non-complex sentences, and also fixated more often on the complex sentences. More figurative language and metaphors in the source text may also make it more difficult to translate and thus increase the cognitive resources necessary for the translation step (Kokanova et al., 2018).

Because the translator continues to view the source text segment while producing the target output (Agrifoglio, 2004), Čeňková (2010) posits that more cognitive resources may be required to reduce lexical interference than in simultaneous interpreting, presumably because of the relative permanence of graphemes as compared to phonemes. In line with this, Chmiel, Janikowski and Cieslewicz (2020) found that during sight translation, students were more likely to incorrectly translate homographs than during simultaneous interpreting. Certainly, some level of inhibition appears necessary when simultaneously reading in one language and producing speech in another (Green & Abutalebi, 2013).

It also seems that directionality may influence resource allocation during sight translation. For instance, reading in an L2 is generally slower than in an L1 (Brysbaert, 2019) and production in L1 is consistently faster than in L2 (Bradlow, Kim, & Blasingame, 2017).

Thus, depending on the direction of translation, the relative effort for comprehension and production might be different.

4.6. Consecutive interpretation

Consecutive interpreting involves the comprehension of an utterance or a series of utterances in the source language, and the subsequent oral translation of the same utterance(s) in the target language. Source and target language are activated in parallel, and in direct relation to one another (the target language output should transmit the same meaning as the source language input). Consequently, consecutive interpreting involves multi-tasking and frequent and regular use of two different languages under time pressure and following an externally determined direction of translation (Dong & Li, 2020).

Consecutive interpreting involves multi-tasking as listeners must listen, memorise and, for longer speeches, take notes while the speaker is speaking. They then render what they have heard, using their memory and their notes, into another language. Consecutive interpreting itself may be divided into the modes of “short consecutive”, when interpreters work on a sentence-by-sentence basis (untrained bilinguals also perform this type of interpreting) and “classic” consecutive, when the interpreter uses a note-taking system to support their memory (Pöchhacker, 2011; Van Dam, 2010). These two modes are, of course, on a spectrum.

Consecutive interpreting places demands on short-term memory and memory retrieval, as interpreters must remember what has been said and reproduce the utterance in the target language (Gile, 1997). It is also likely that the process draws on long-term memory (Pöchhacker, 2011). Note-taking has an analytical component, as interpreters must note down the most salient content necessary to reproduce the series of utterances (Gile, 1997; Piolat, Olive, & Kellogg, 2005). In other words, note-taking involves elements of problem solving and decision making (Piolat et al., 2005). Note-taking itself requires that the interpreter be able to "read" their notes (Chen, 2017), which do not contain all the content of the speech and instead include abbreviations and symbols that cue the retrieval of concepts stored in long-term memory (Seleskovitch, 1975) (although some of the symbols may also cue the retrieval of concepts from short-term memory). Abbreviations and words jotted down in the interpreter's notes may be in the source or the target language (Pöchhacker, 2011).

The time element of selecting and noting key points of the original discourse while comprehending new information at the same time requires significant cognitive resources (Piolat et al., 2005). Where this time pressure is increased, for example, when a source language utterance is produced at a faster speed, this is likely to increase cognitive load.

Greater automatization of some of these processes (Chmiel, 2006), for example, being used to noting down a particular symbol to represent a specific meaning, or automatising the truncation of words noted down (e.g., noting *poss.* for possibility) might lead to greater availability of cognitive resources for other parts of the task, for example, comprehending the message. As anticipating relevant information is necessary for note-taking (Piolat et al., 2005), greater predictability of the source language utterance may reduce cognitive load (although we must bear in mind that predicting upcoming language may itself require cognitive resources, see Ito, Corley, & Pickering, 2017).

Of course, the interpreter must use the notes they have taken during the comprehension step to jog their memory while reproducing the speech in the target language, and this combined note-reading and production step also involves cognitive resources. In an eye-tracking study, Chen, Kruger and Doherty (2021) found that at the note-taking stage, professional interpreters laid out their notes in different groups, which contributed to facilitating cognitive processing during the production stage. They also found that certain elements in notes were more difficult to process than others: for instance, interpreters found it more cognitively demanding to process whole words than symbols during note-reading and production (as measured by first fixation duration and first-pass dwell time).

4.7. Simultaneous interpretation

Unlike in consecutive interpreting, a process hallmarked by the speaker and the interpreter taking turns to speak, in simultaneous interpreting the oral comprehension of the source language and the oral production of the output in the target language temporally overlap. That, combined with fact that, as opposed to sight translation, both the input and the output are auditory turn simultaneous interpreting into one of the most complex language processing tasks the human mind is capable of (see Seeber, 2017). The temporal constraints the task imposes on the interpreter, generally allowing no more than two to three seconds to lapse between the beginning of the original utterance and the interpretation (Timarová, 2015), are indeed considerable. The variation of this ear-voice-span (EVS) has been proposed as a way for interpreters to actively modulate local load (Defrancq, 2015; Timarová et al. 2014) in order to accommodate scarce processing resources. Indeed, the limited capacity of the working memory construct (Baddeley & Hitch, 1974), along with Kahneman's (1973) notion of cognitive effort, has defined the attempt to capture the inherent processing constraints conditioning simultaneous interpreting (Moser-Mercer, 1997). Gile's (1985) effort models attribute process breakdowns to the mismatch between available resources for the conjectured tasks of listening, producing, memorizing and coordinating (among which they can be deliberately allocated) on one hand, and the respective requirements on the other. Broadening this view to include the notions of load and interference, Seeber (2011) illustrates how the load generated by particular cognitive component tasks of simultaneous interpreting will vary depending on three task dimensions (stage, code and modality) as well as the degree of interference generated by them (see Wickens, 1984).

It is the need to control and allocate attention to two simultaneously executed tasks (comprehension in one language and production in the other), however, that, early on, triggered psycholinguists' interest in the task (Barik, 1973; Gerver, 1974;Oléron & Nanpon, 1965) and, more recently, has led scholars to describe simultaneous interpreting as extreme language use (de Groot 2011; Hervais-Adelman & Babcock, 2020, Hervais-Adelman, Moser-Mercer, & Golestani, 2015, Yudes, Macizo, & Bajo, 2012). Recently, however, it has been suggested that consecutive interpreting might generate similar amounts of cognitive load (Lv & Liang, 2018). It would seem that the amount and regularity of language switching in simultaneous interpreting (Dong & Li, 2020) requires different types of control mechanisms (see Miyake & Friedman, 2012), altering the neurophysiological structures of experienced professional simultaneous interpreters (Dong &Zhong, 2017; Van de Putte, De Baene, Garcia Penton, Wouman, Dijkgraaf, & Duyck, 2018). Whether these are general executive control functions, more specific language control functions, or both, they appear to condition the task owing to inherent capacity limits (de Groot & Christoffels, 2006; Hervais-Adelman & Babcock 2020; Darò & Fabbro, 1994; Paradis, 1994;).

More recently, and perhaps conditioned by the way in which distance interpreting modalities are affecting the interpreting process, the multimodal nature of processing during simultaneous interpreting (Seeber, 2017) has generated more interest, especially when the auditory input is accompanied by visual input, either through slides, manuscripts or human or machine-generated captions (Seeber, Keller, & Hervais-Adelman, 2020). Whether the availability of redundant and complementary information presented in a different code or modality in real time allows for better resource allocation and, thus, the reduction of load, is unclear, as the scant empirical data are currently inconclusive (Chmiel et al., 2020; Defrancq & Fantinuoli, 2021).

5. Conclusion

In this chapter we have taken a closer look at monolingual and multilingual comprehension and production as underlying processes of more complex language-processing tasks such as shadowing, paraphrasing, respeaking, written translation, post editing, sight translation as well as consecutive and simultaneous interpreting. We have seen how the deeply intertwined constructs of capacity, load and effort can provide an adequate framework to describe the processing constraints experienced during the performance of these tasks especially also the impact of factors such as speed, modality or directionality. Yet, as the discussion of their application to different tasks shows, we are only just starting to understand these theoretical constructs, how they interact and how to apply them. The notion of capacity, for example, has been viewed as relating to memory, attention or control. Similarly, load and effort are generally understood as discrete phenomena, yet often still used interchangeably. These limitations, however, do not detract from our conviction that, much like in other areas of complex learning (van Merriënboer & Sweller, 2005) these constructs hold the potential of being operationalized in training environments allowing for more efficient and effective acquisition of the skills underpinning these language-processing tasks (see van Egdom, Cadwell, Kockaert & Segers, 2020 for an overview). While the challenge is not negligible, we are profoundly convinced that, as a field, we have the capacity, so long as we are willing to invest the effort.

6. References

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